US009318542B2

(12) **United States Patent**
Choi et al.

(10) **Patent No.: US 9,318,542 B2**
(45) **Date of Patent: Apr. 19, 2016**

(54) **METHOD FOR FABRICATING ORGANIC LIGHT EMITTING DIODE DISPLAY DEVICE WITH IMPROVED EFFECTIVE EMITTING PIXELS AREA**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/012,321**

(22) Filed: **Aug. 28, 2013**

(65) **Prior Publication Data**

US 2014/0145158 A1 May 29, 2014

(30) **Foreign Application Priority Data**

Nov. 26, 2012 (KR) 10-2012-0134299

(51) **Int. Cl.**
H01L 27/32 (2006.01)
H01L 51/52 (2006.01)
H01L 51/50 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 27/3246*** (2013.01); ***H01L 27/3248*** (2013.01); ***H01L 27/3262*** (2013.01); ***H01L 51/5012*** (2013.01)

(58) **Field of Classification Search**
CPC . H01L 51/0005; H01L 51/5265; H01L 51/56; H01L 27/3246
USPC 438/29, 34, 46, 82, 149, 780; 257/40, 257/88, 98; 313/503, 504
See application file for complete search history.

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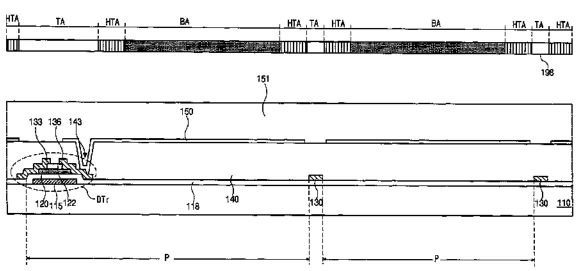
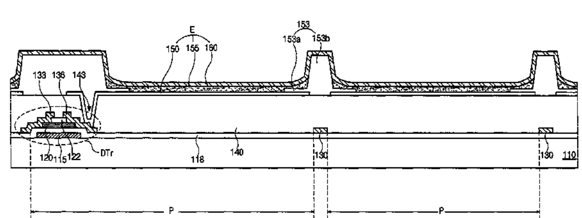
(57) **ABSTRACT**

An organic light emitting diode display device includes a substrate including a display region, wherein a plurality of pixel regions are defined in the display region; a first electrode over the substrate and in each of the plurality of pixel regions; a bank including a lower layer and an upper layer on the first electrode, the lower layer disposed on edges of the first electrode and having a first width and a first thickness, the upper layer disposed on the lower layer and having a second width smaller than the first width; an organic emitting layer on the first electrode and a portion of the lower layer; and a second electrode on the organic emitting layer and covering an entire surface of the display region.

10 Claims, 25 Drawing Sheets





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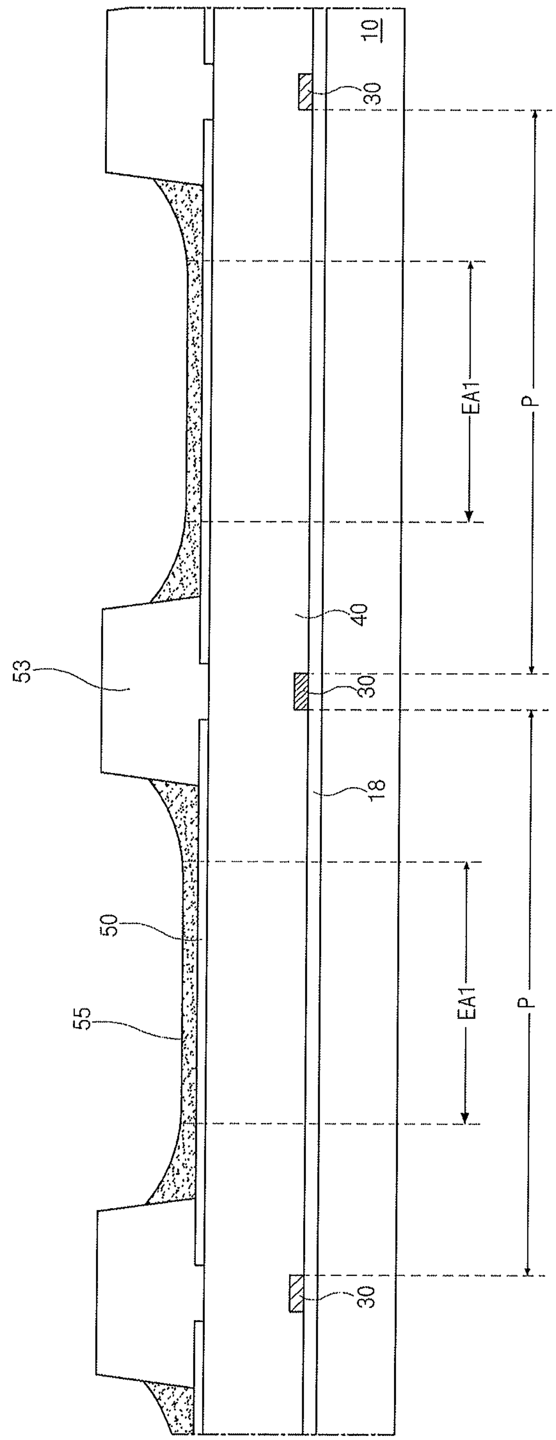


FIG. 1
Prior Art

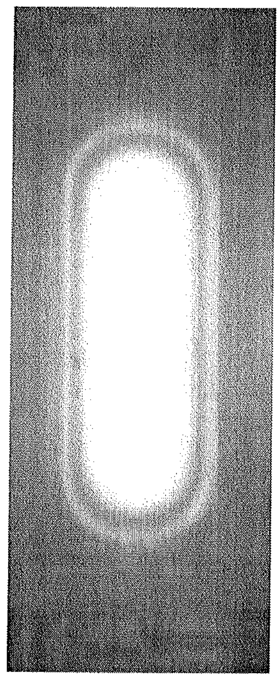


FIG. 2
Prior Art

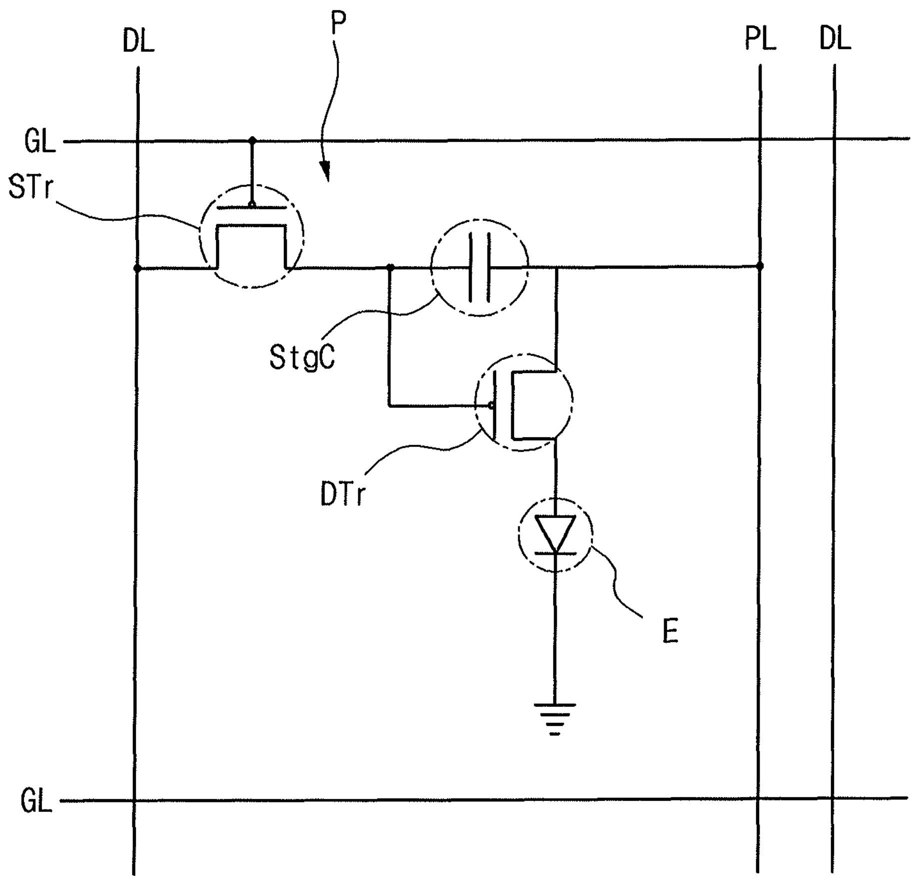
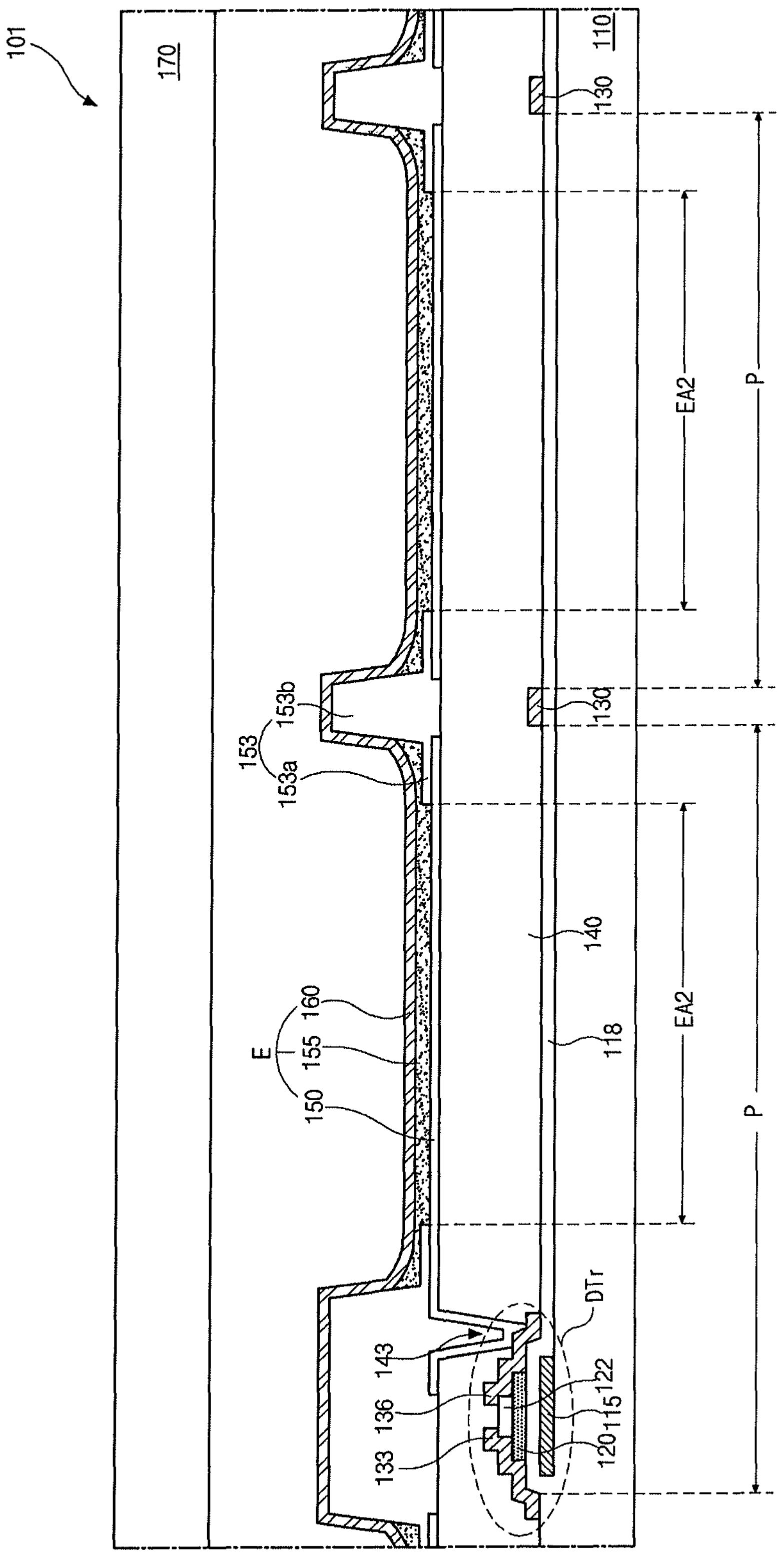


FIG. 3


101
170
110
130
130
EA2
EA2
P
P
153
153a
153b
140
118
E
150
155
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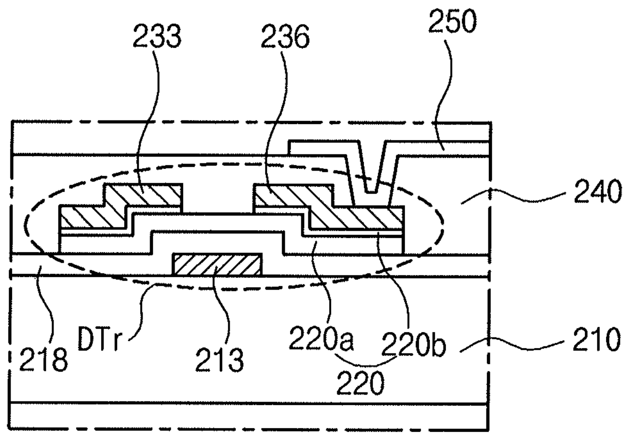
DTr
143
136
133
122
115
120

FIG. 4


233
236
250
240
218
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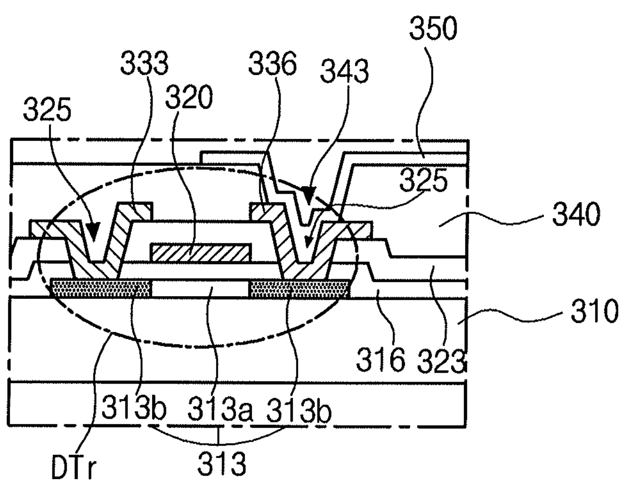
213
220a
220b
220
210

FIG. 5


350
333
336
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320
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325
340
310
316
323
313b
313a
313b
DTr
313

FIG. 6

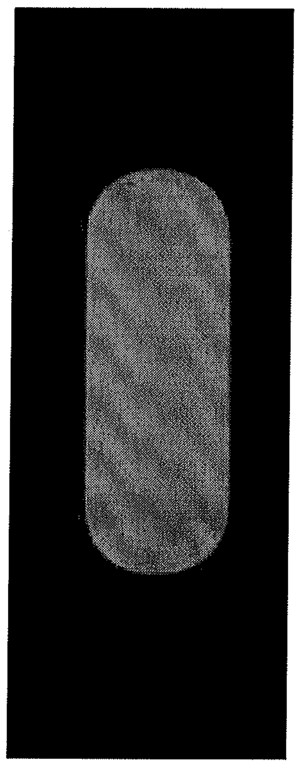


FIG. 7

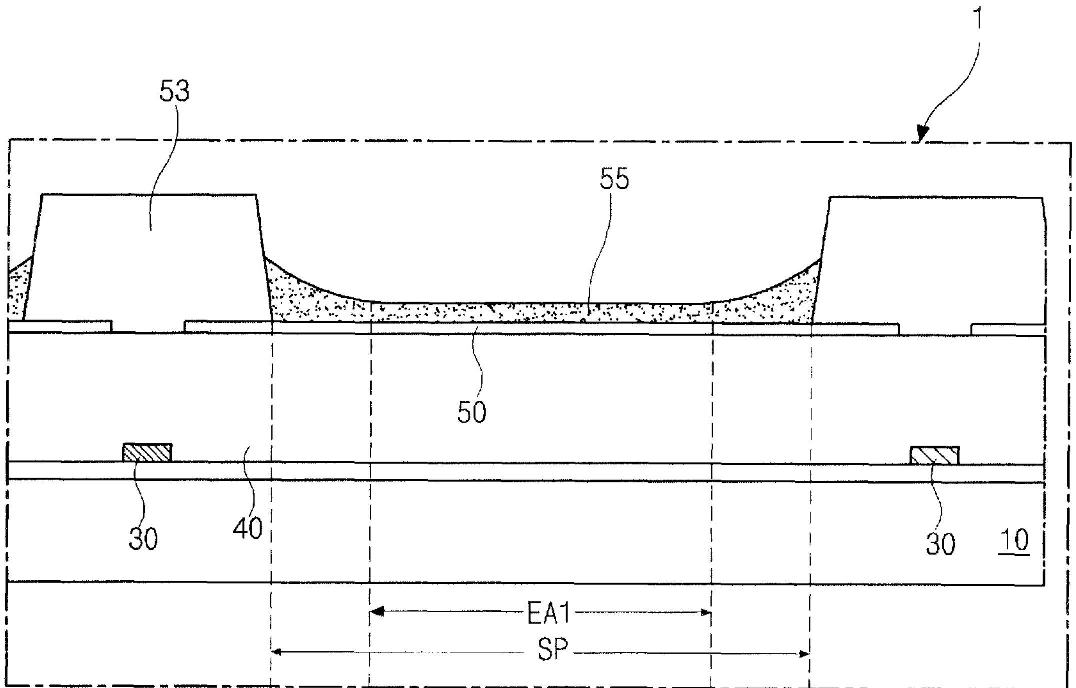


FIG. 8A (Prior Art)

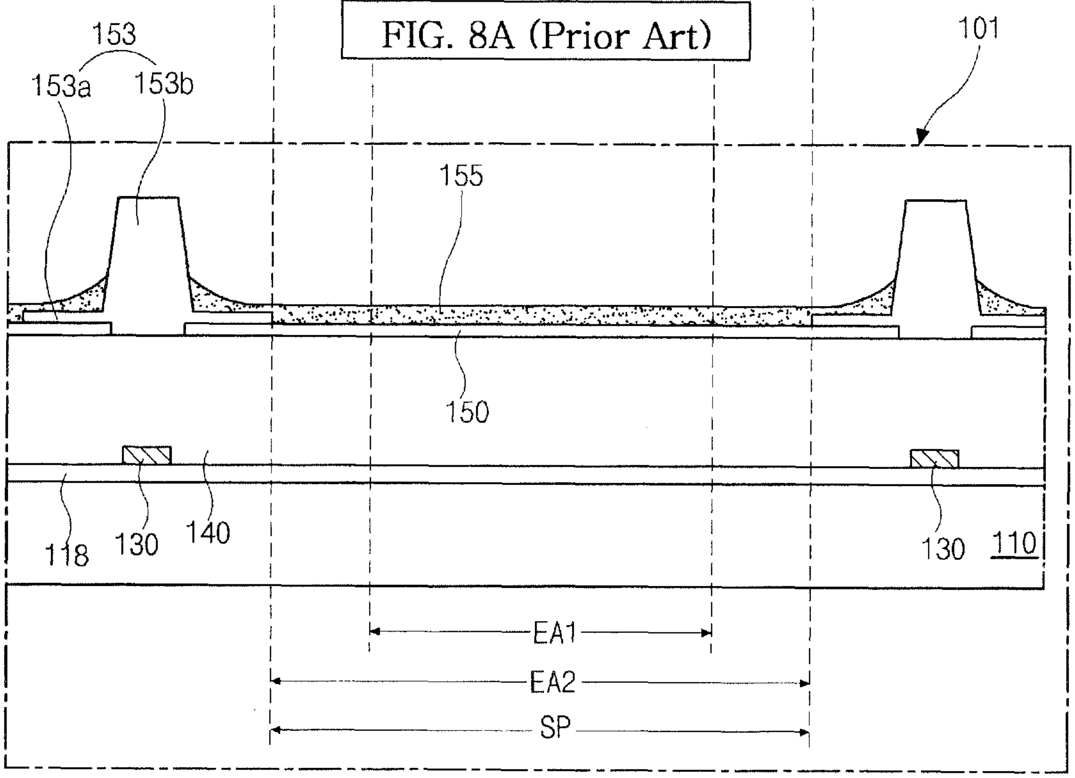


FIG. 8B

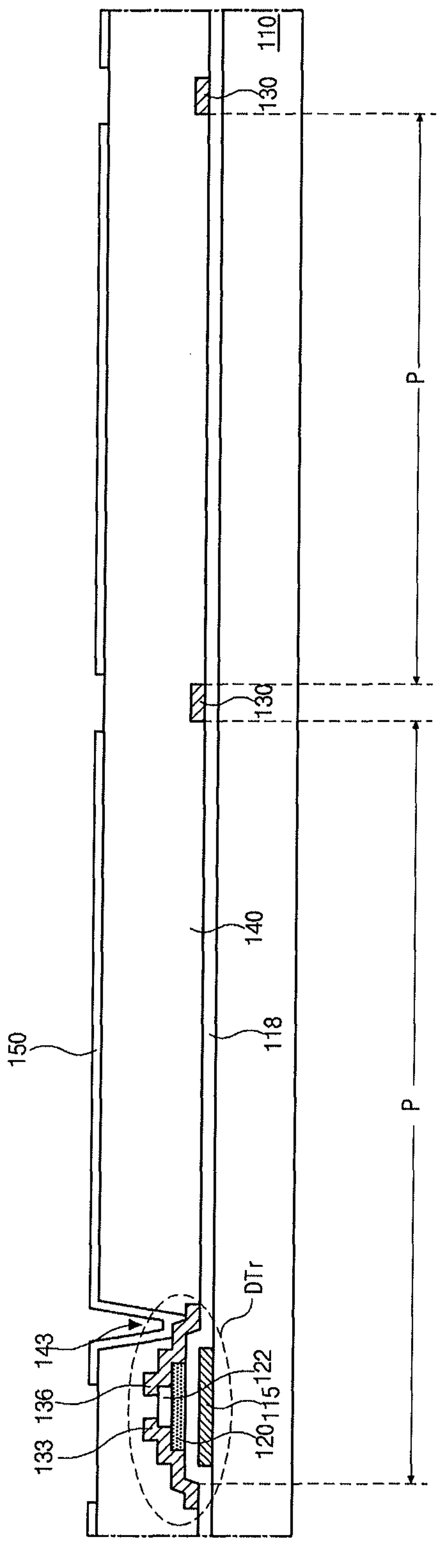
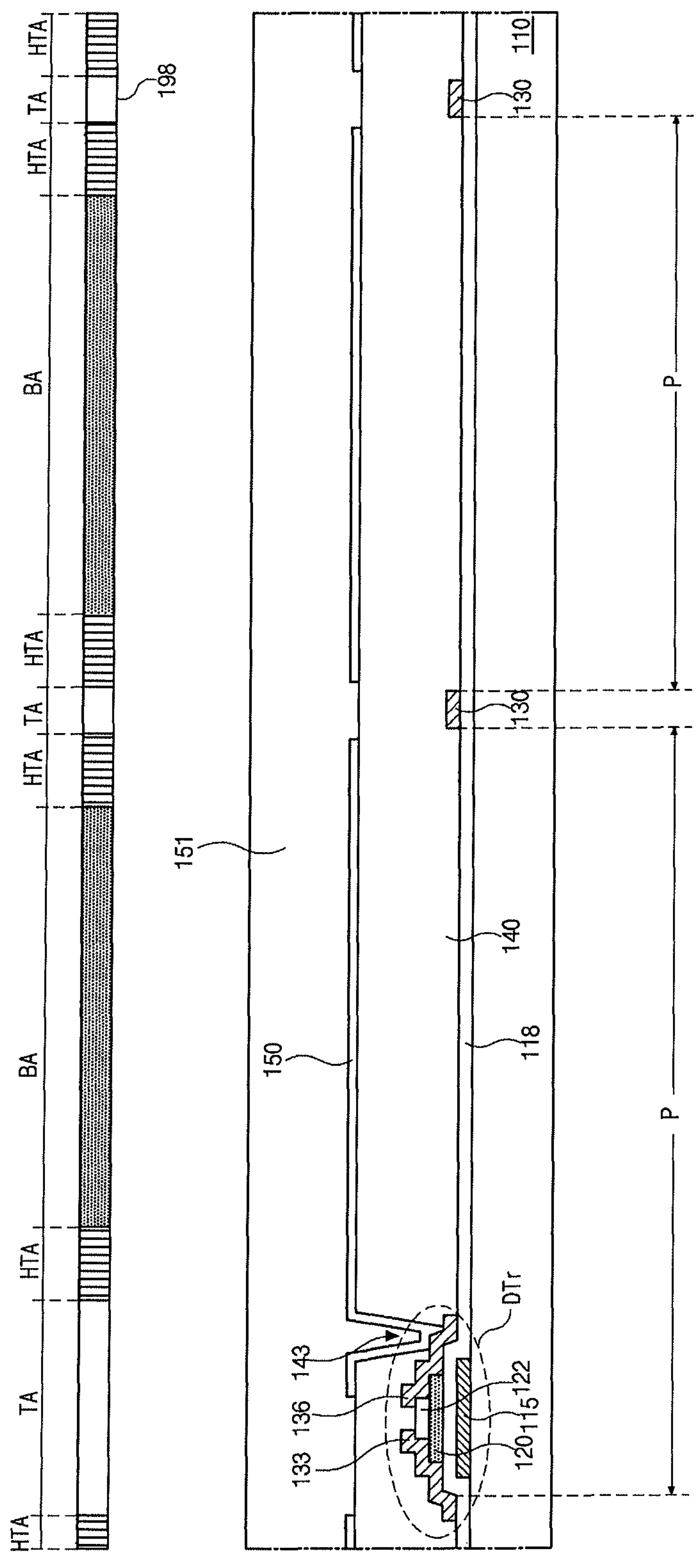


FIG. 9A


HTA
TA
HTA
BA
HTA
TA
HTA
BA
HTA
TA
HTA
198
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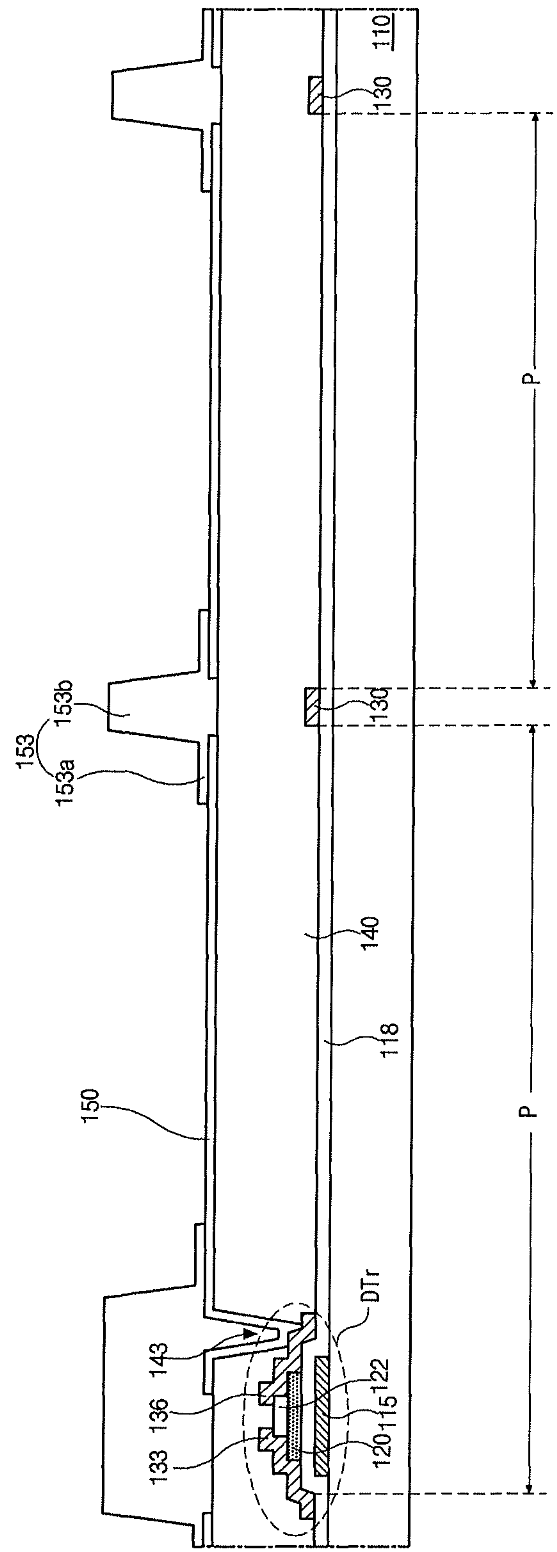
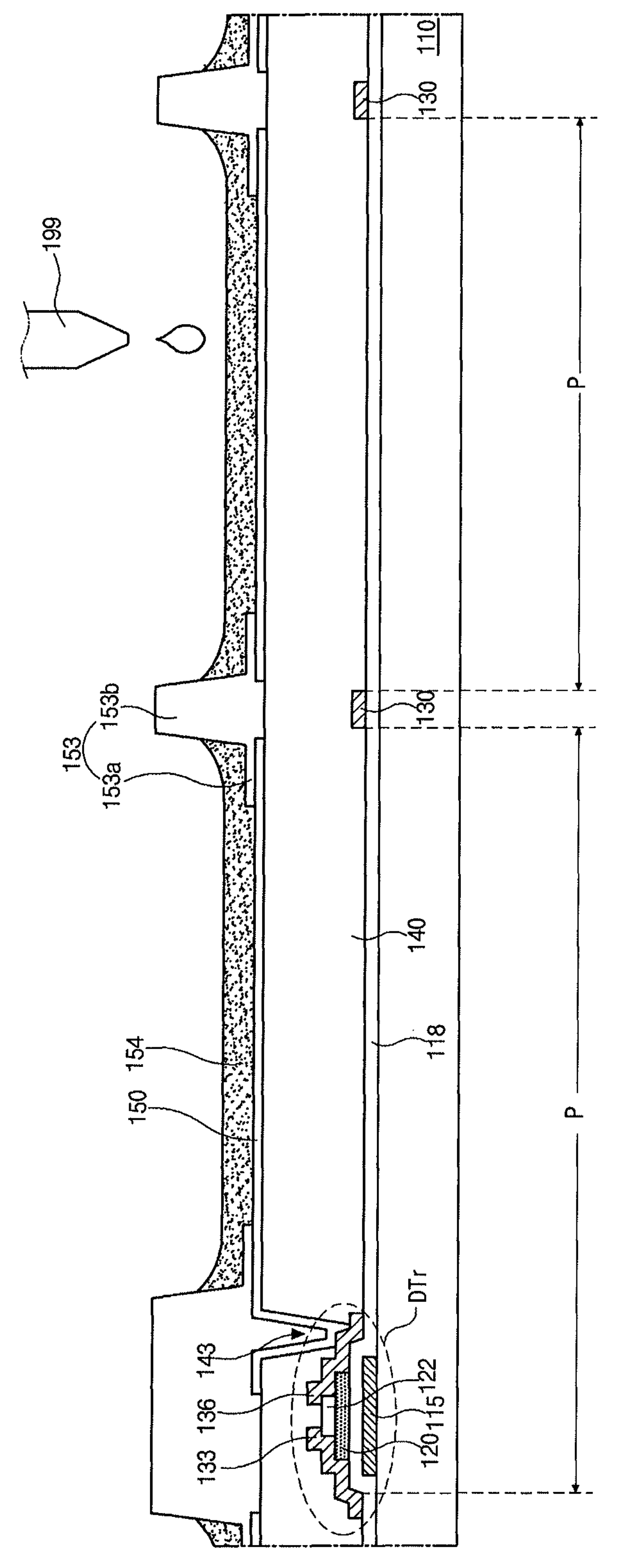
130
151
140
150
118
P
P
DTr
143
136
133
122
115
120

FIG. 9B



110
130
130
P
P
153
153a
153b
140
118
150
DTr
143
136
133
122
115
120

FIG. 9C


110
130
199
P
153
153b
153a
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154
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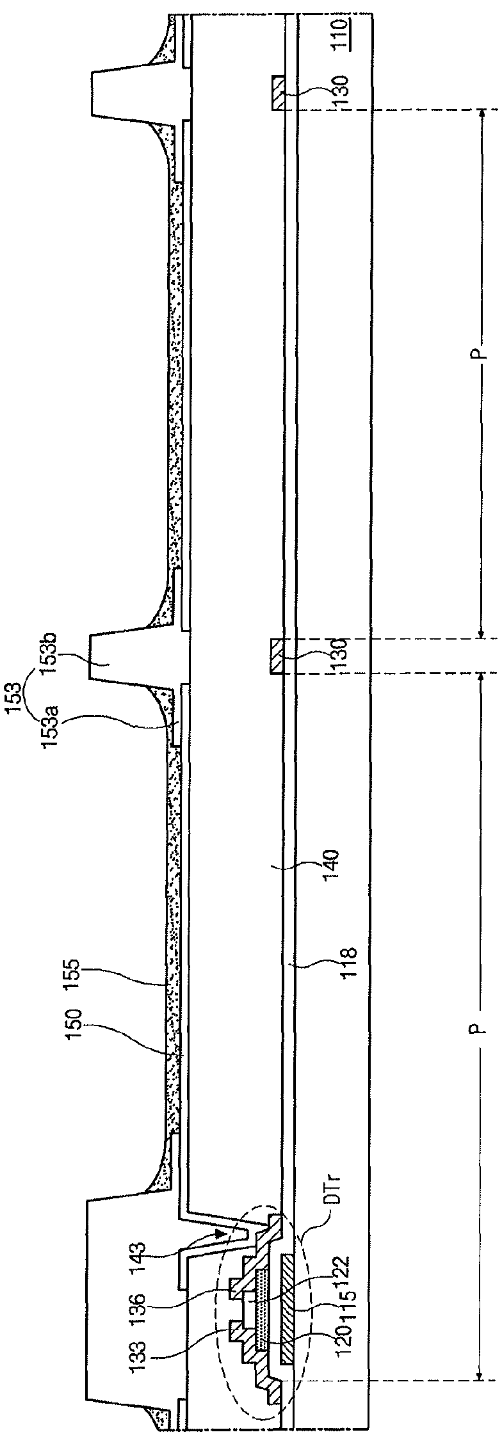
P
DTr
143
136
133
122
115
120

FIG. 9D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130
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P
DTr
143
136
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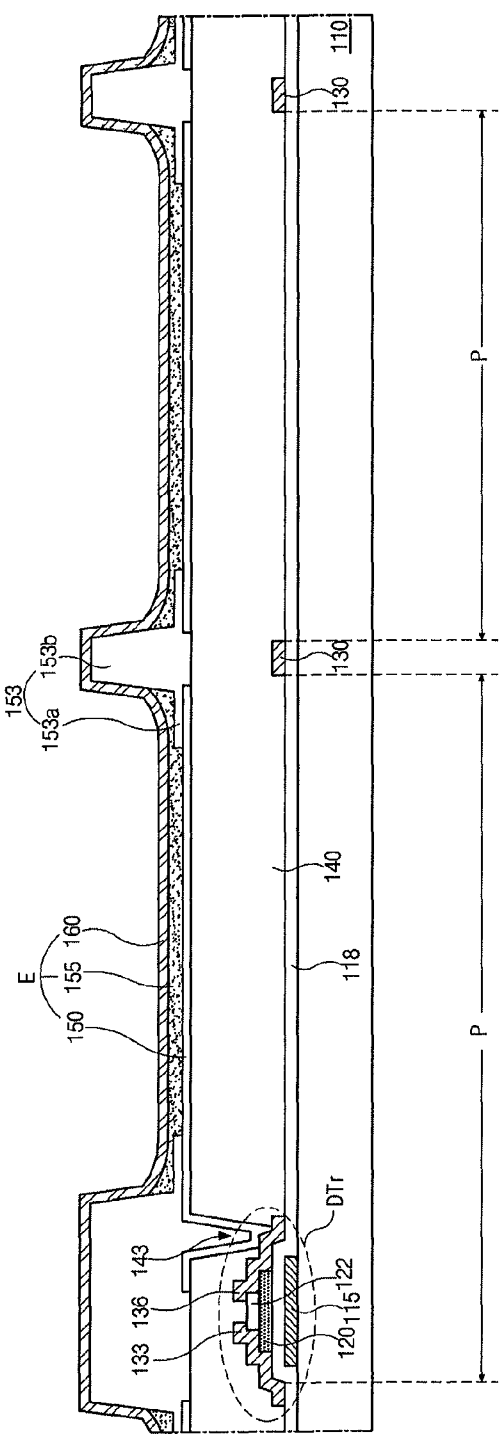
115
120

FIG. 9E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130
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P
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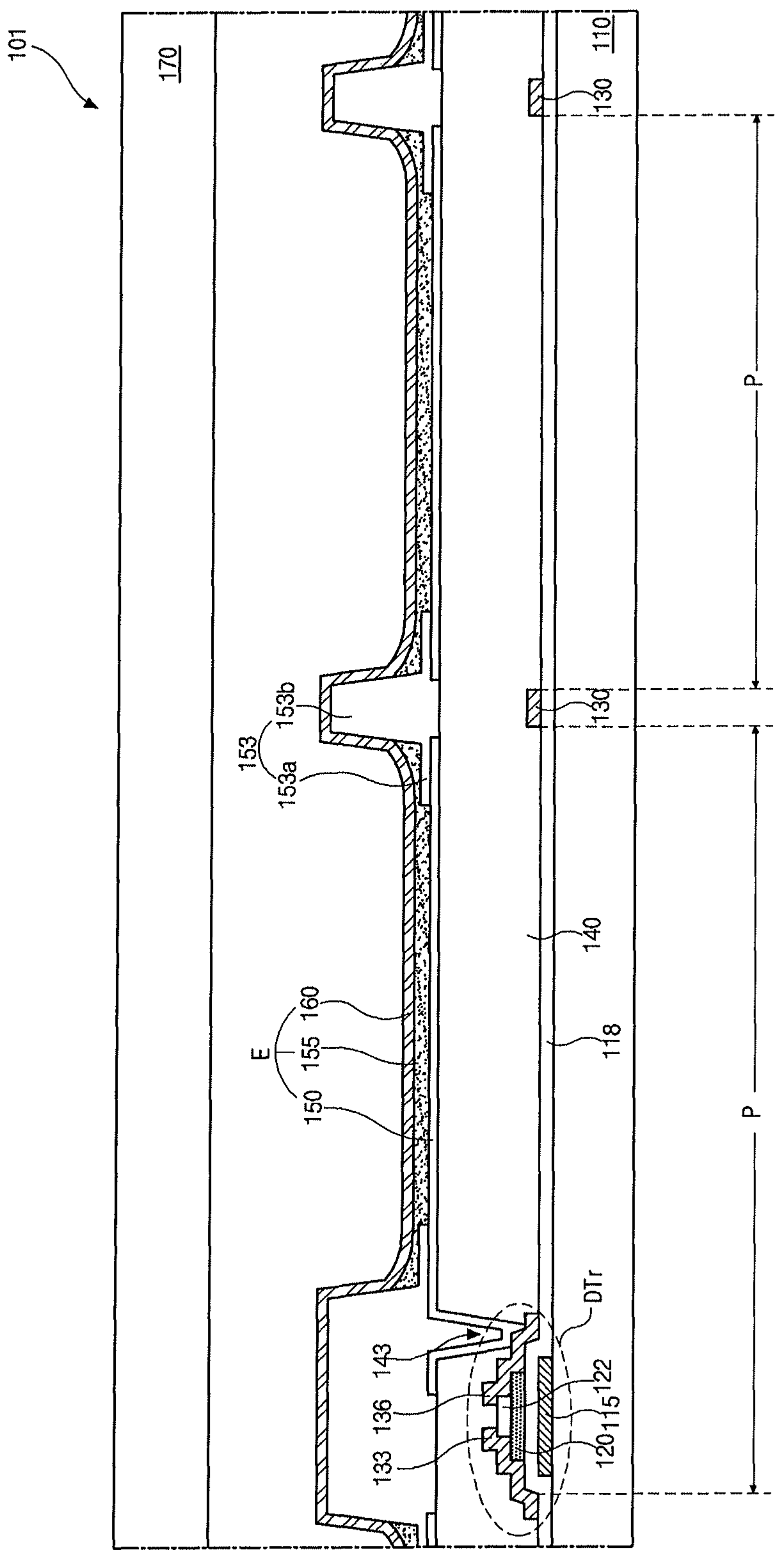
115
120

FIG. 9F


101
170
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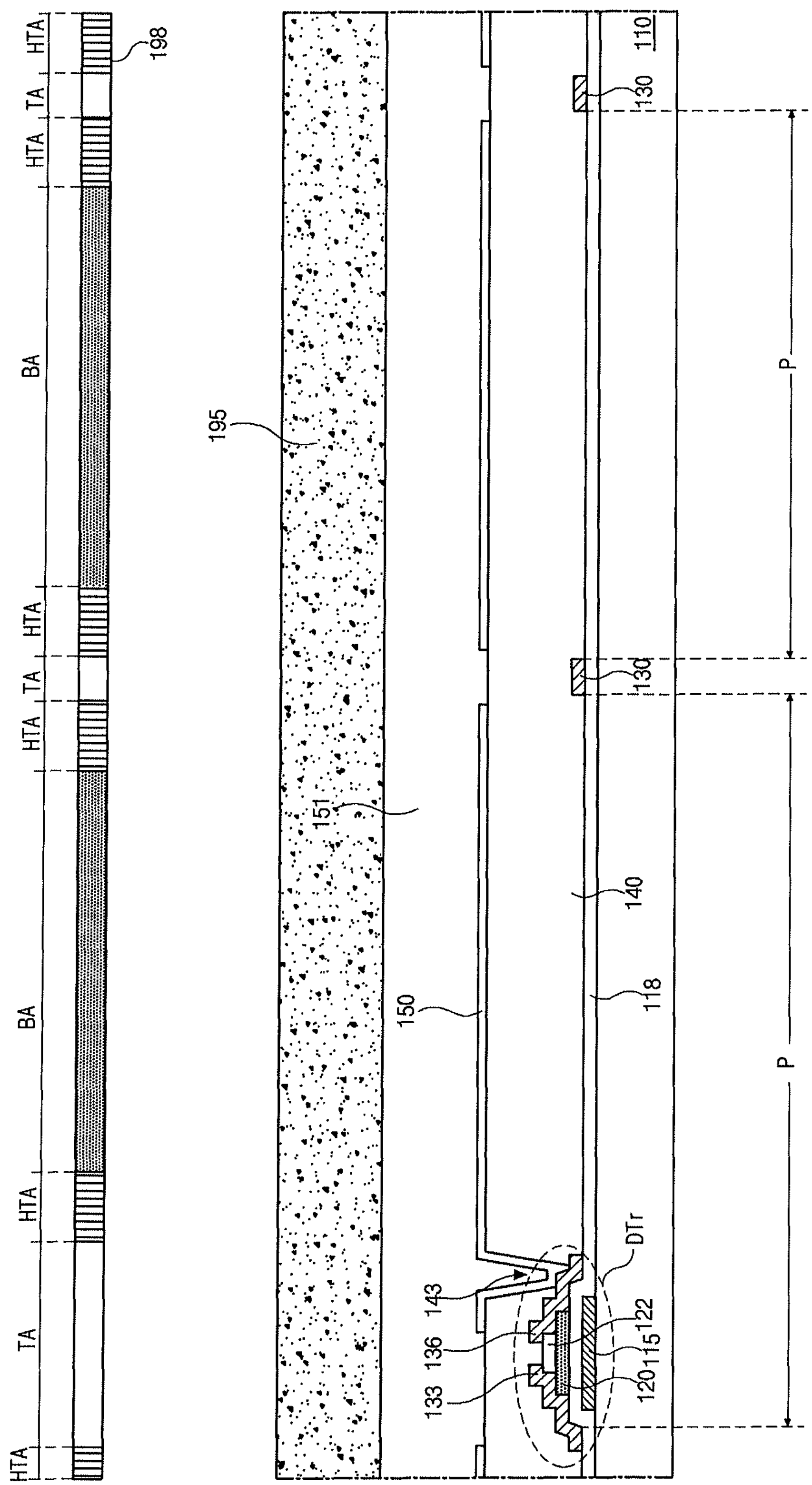
133
122
115
120

FIG. 9G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TA
HTA
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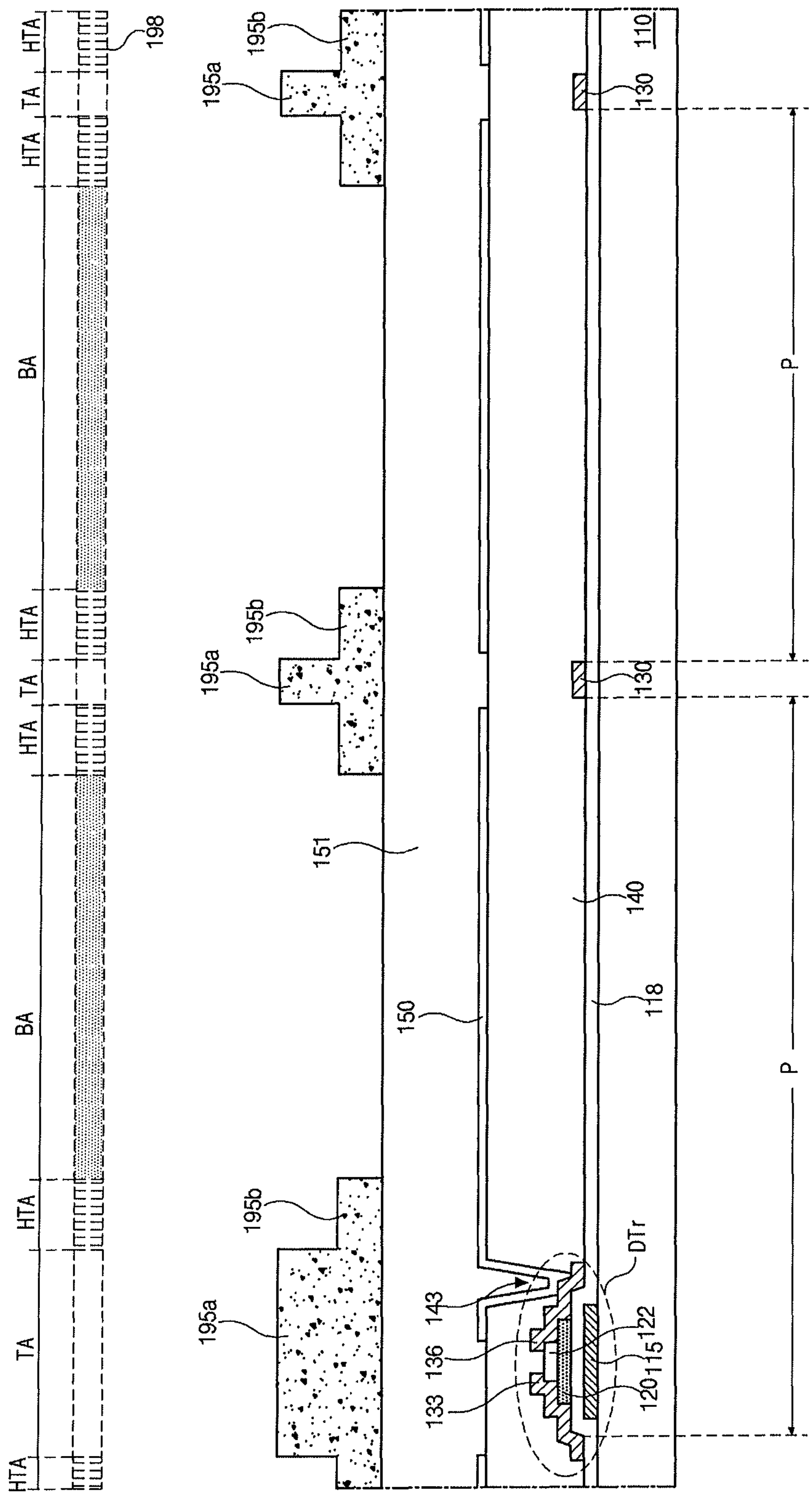
140
118
110
130
130
P
P
DTr
122
115
120

FIG. 10A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115
120

FIG. 10B

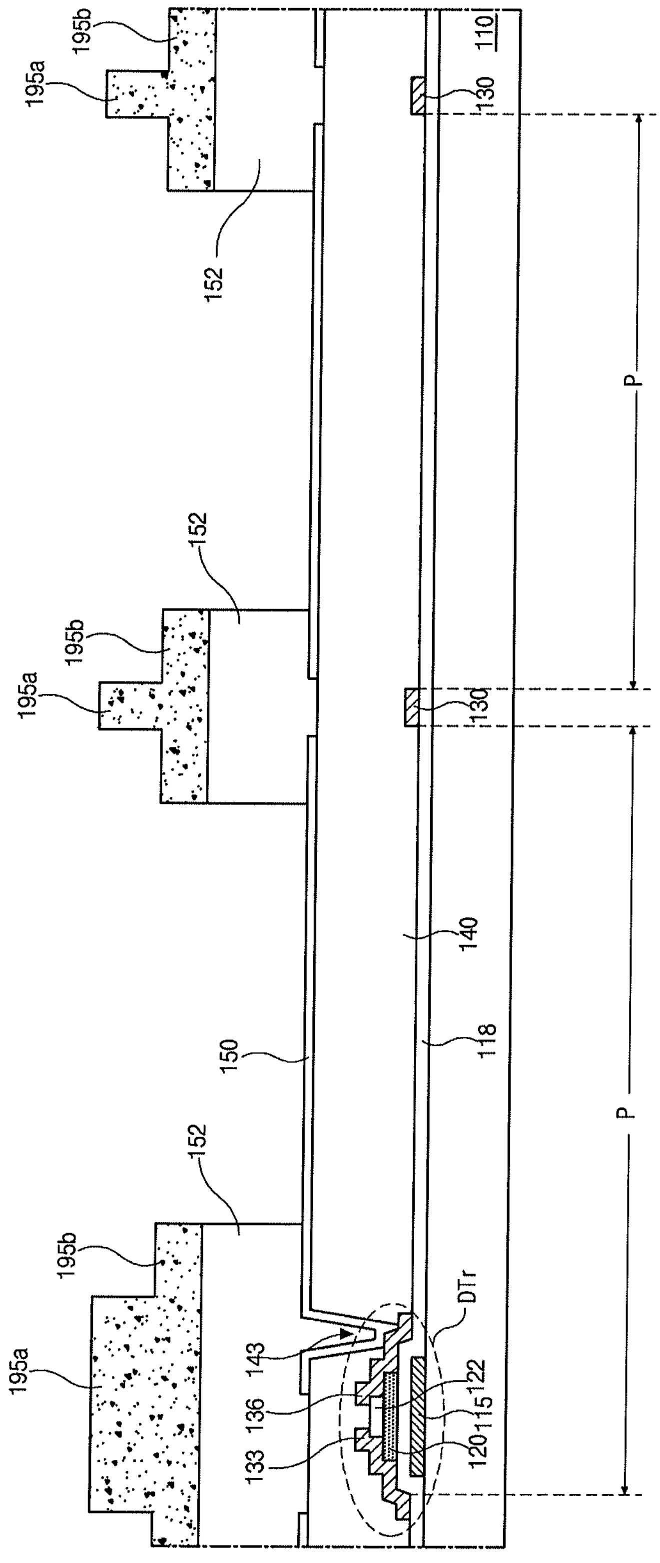
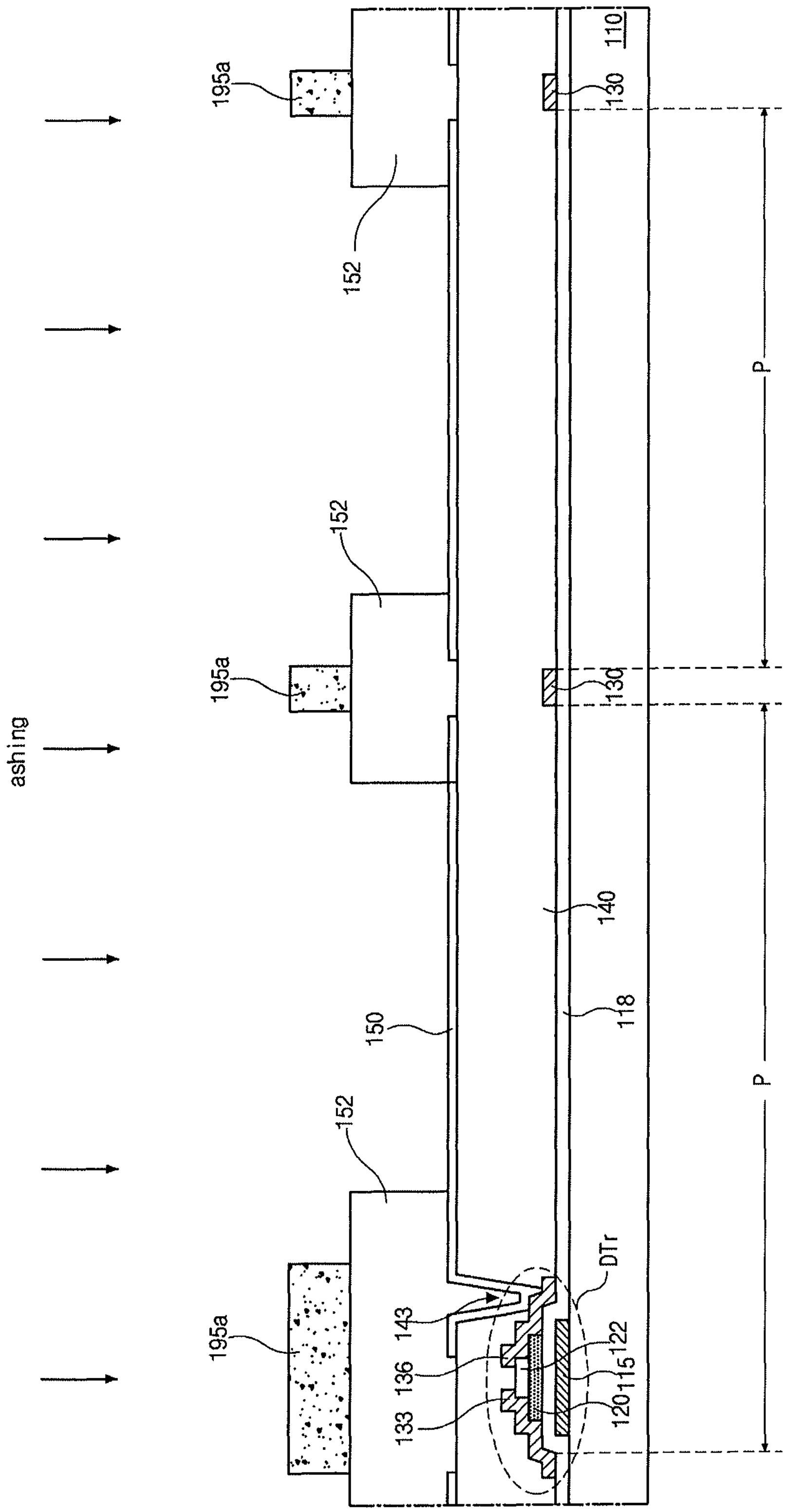


FIG. 10C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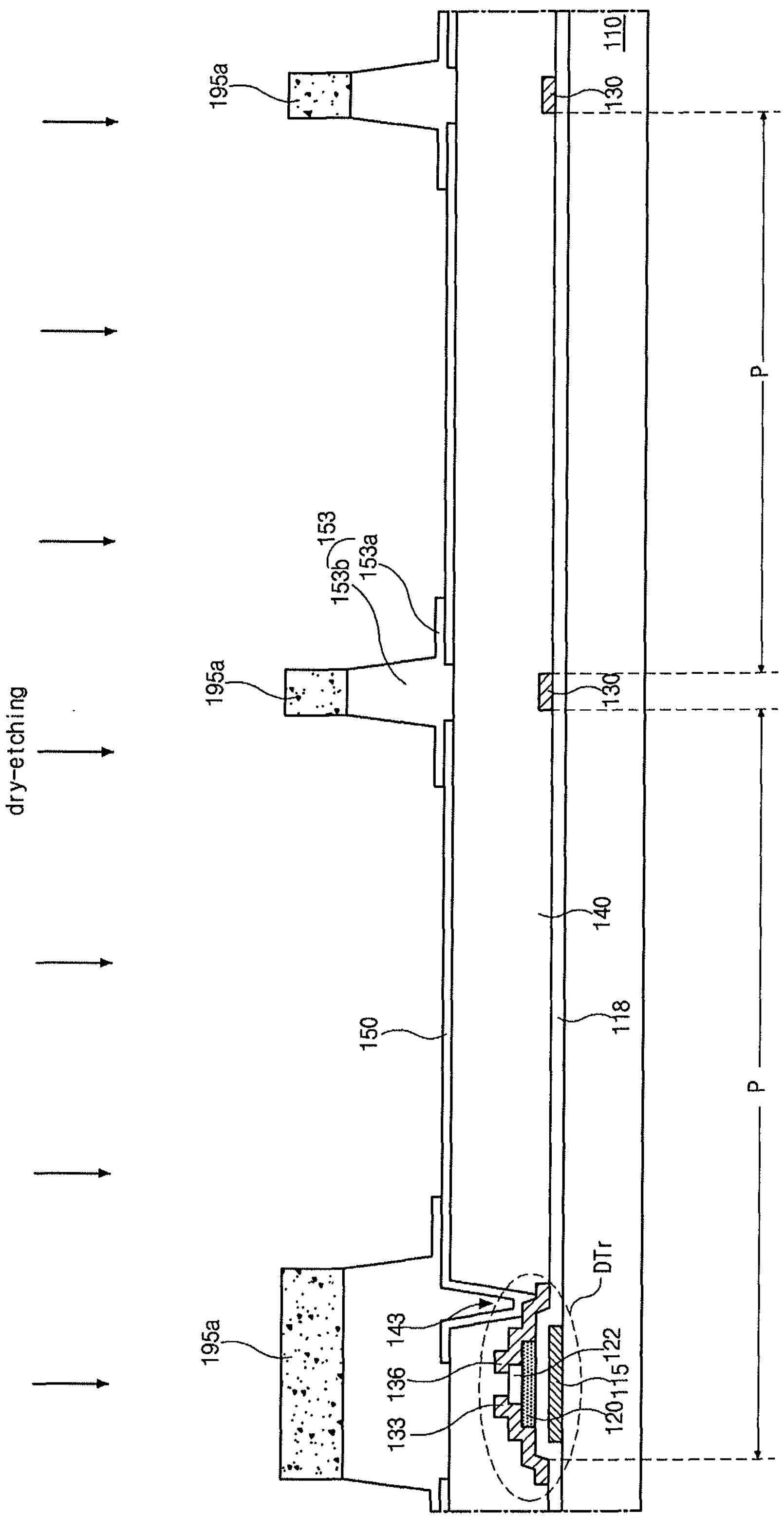
143
136
133
120
115
122
DTr
140
118
130
110
P

FIG. 10D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153
153b
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195a
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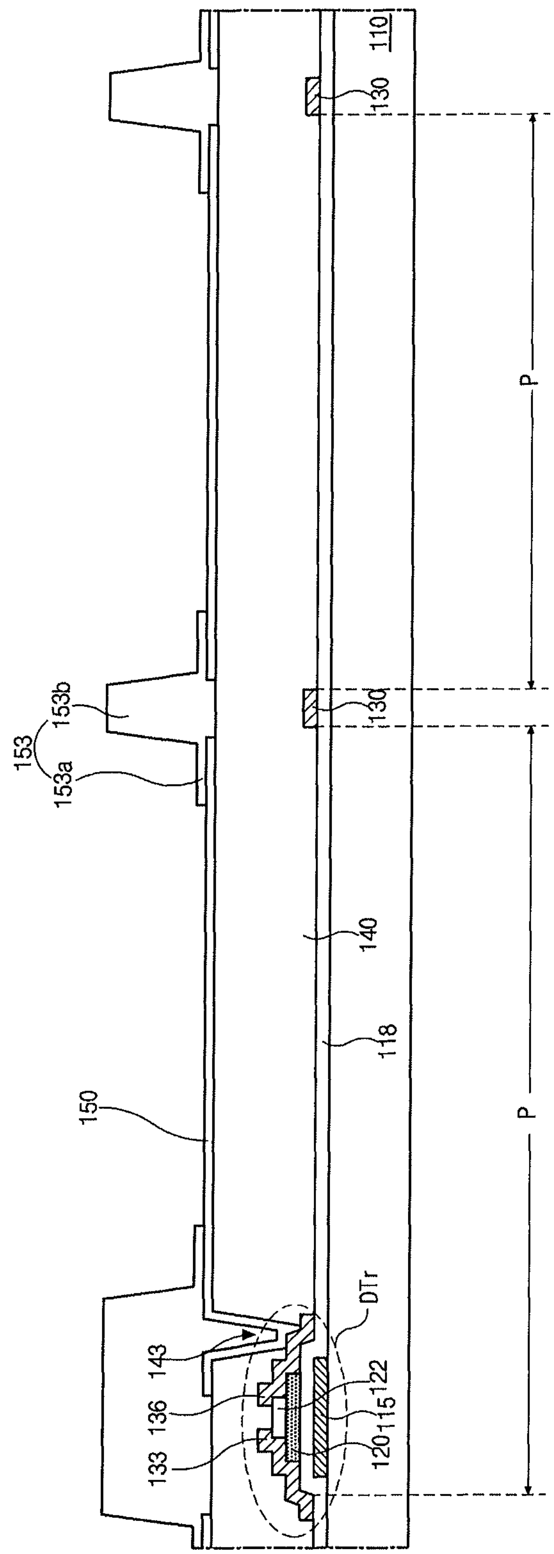
P
140
118
150
P
DTr
195a
143
136
133
122
115
120

FIG. 10E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153b
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P
DTr
143
136
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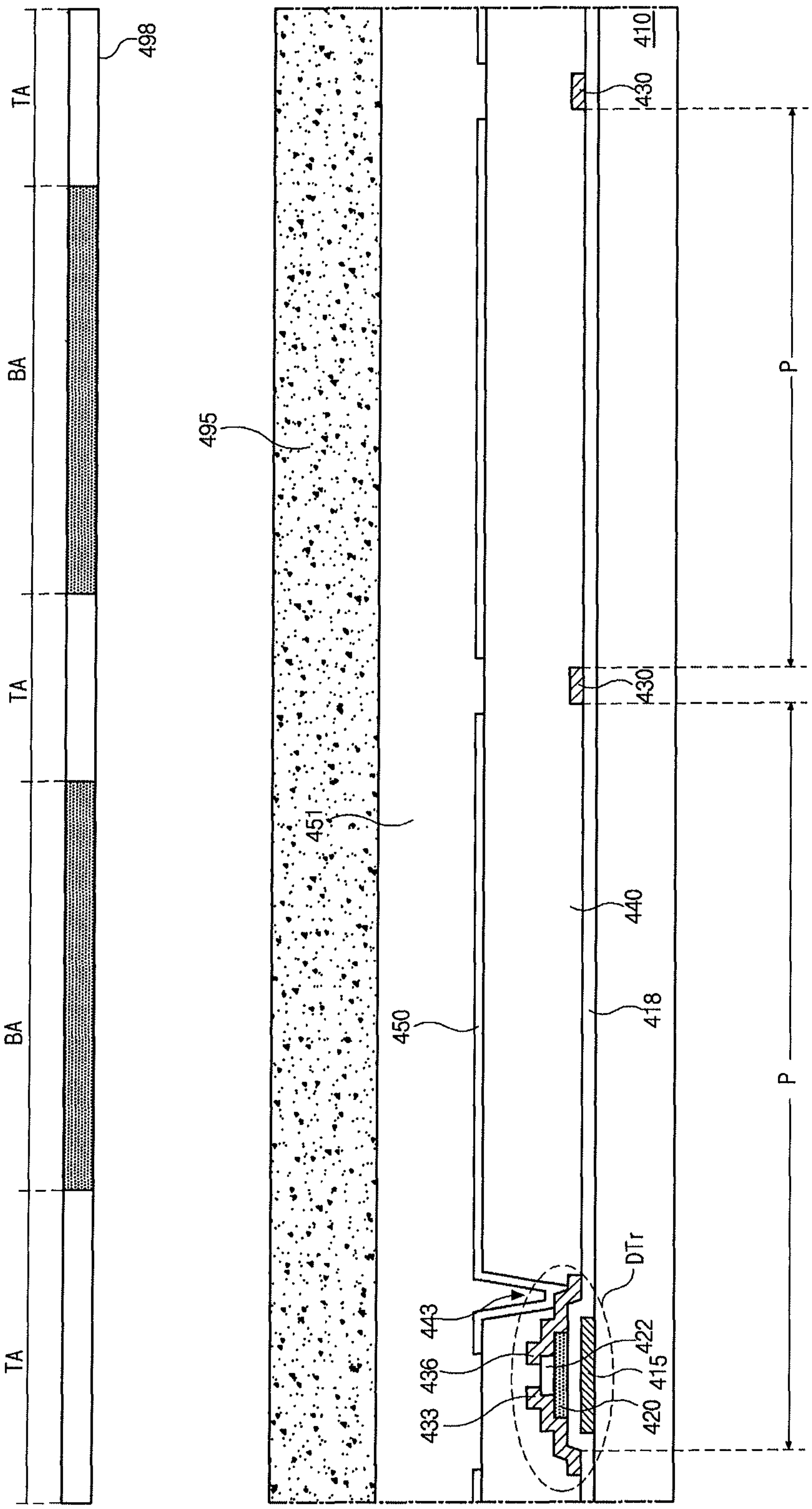
122
115
120

FIG. 10F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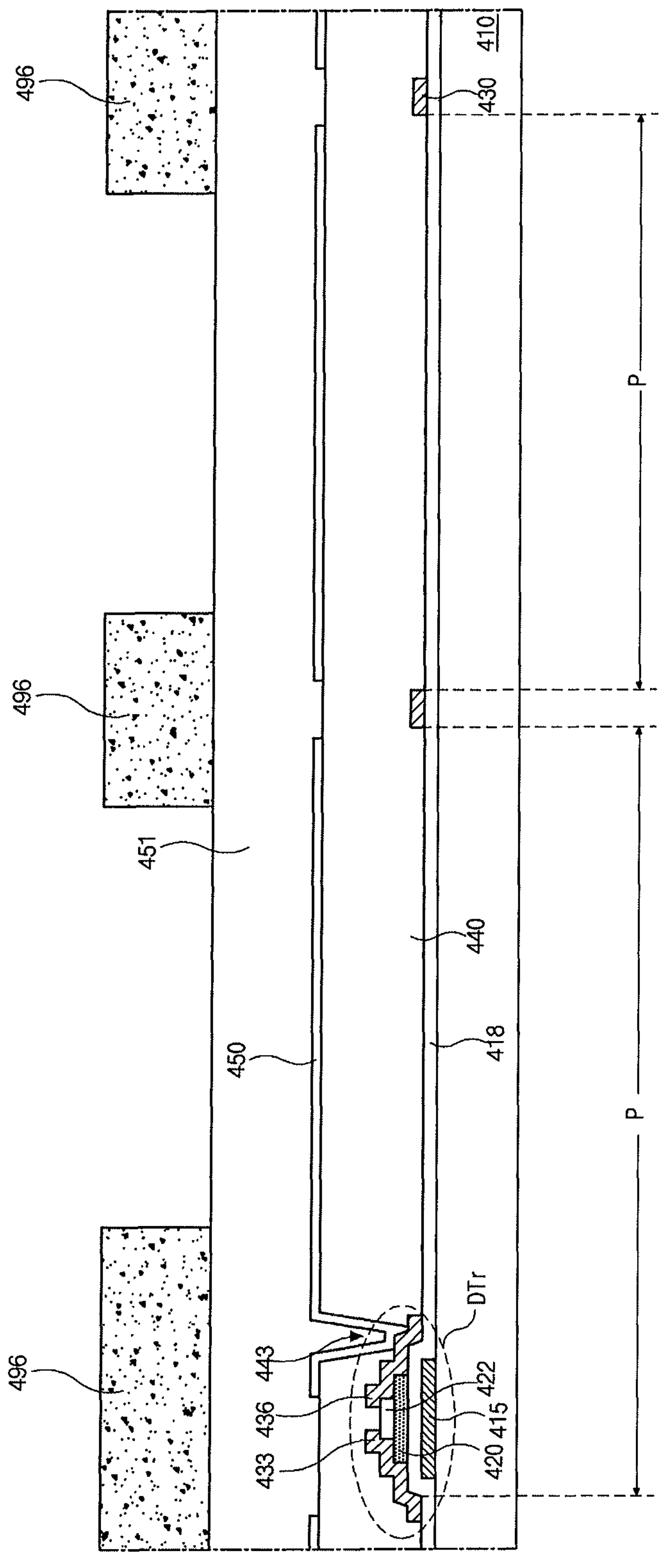
DTr
422
415
420

FIG. 11A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415
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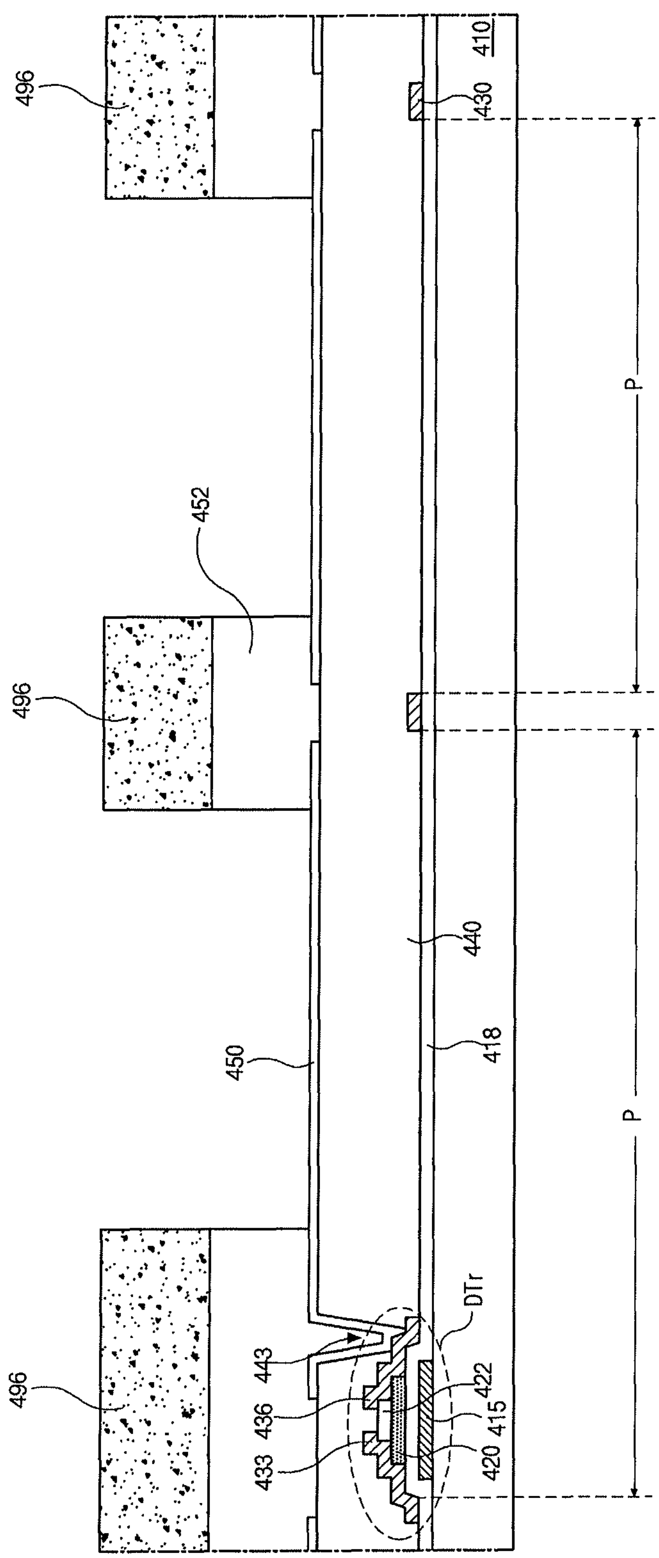
FIG. 11B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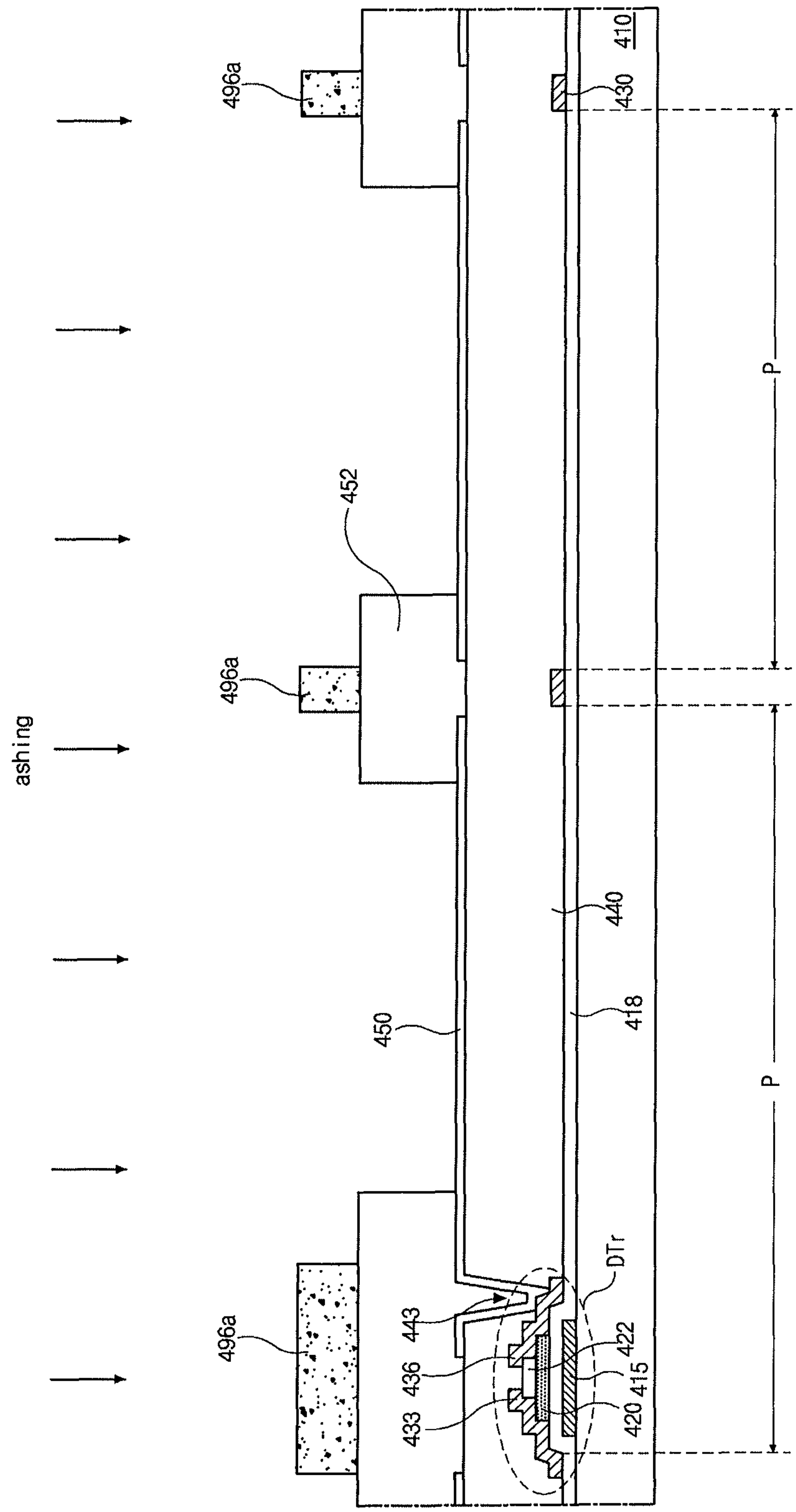
496

FIG. 11C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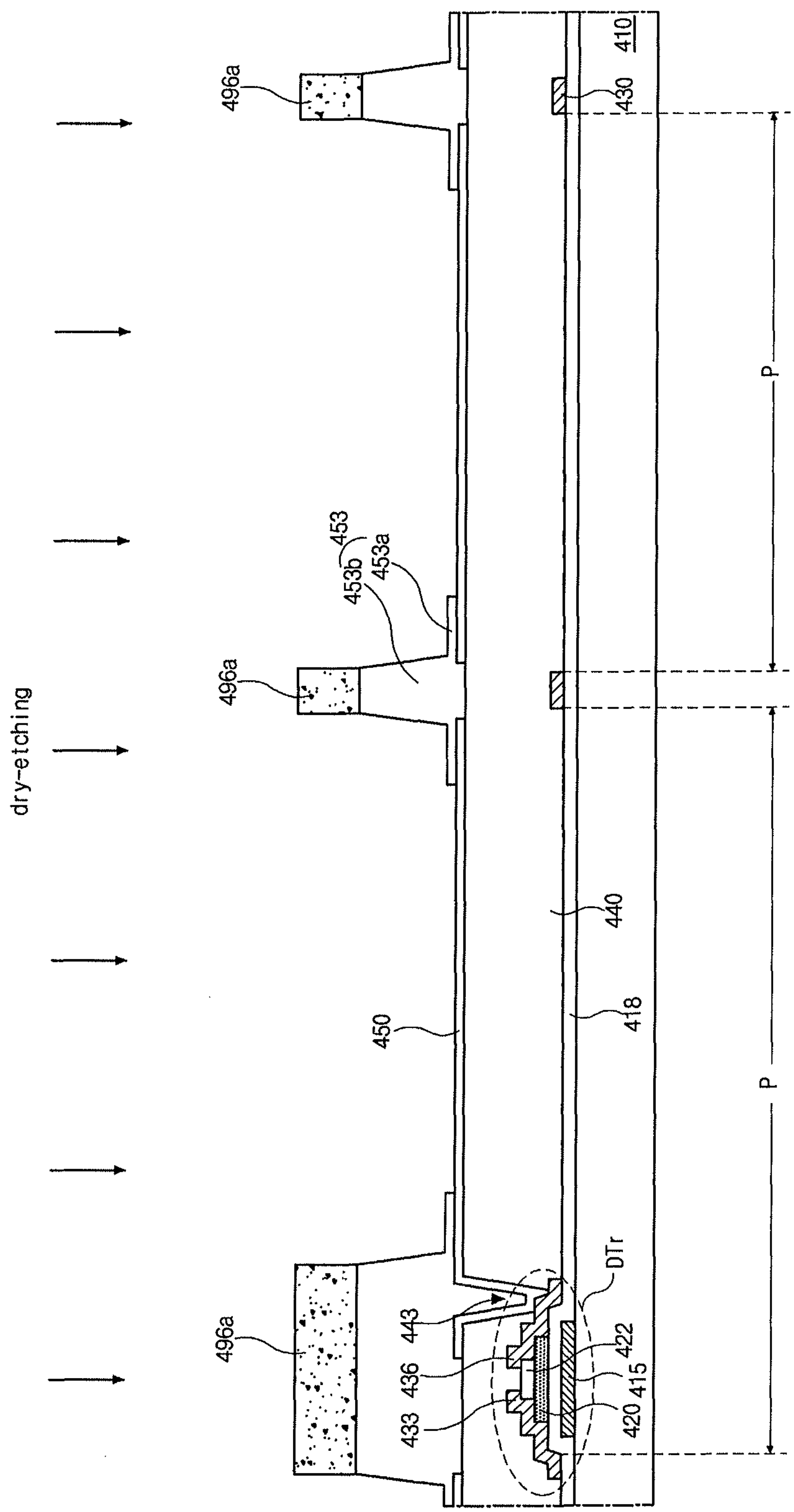
P
P

FIG. 11D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DTr
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436
433
422
415
420

FIG. 11E

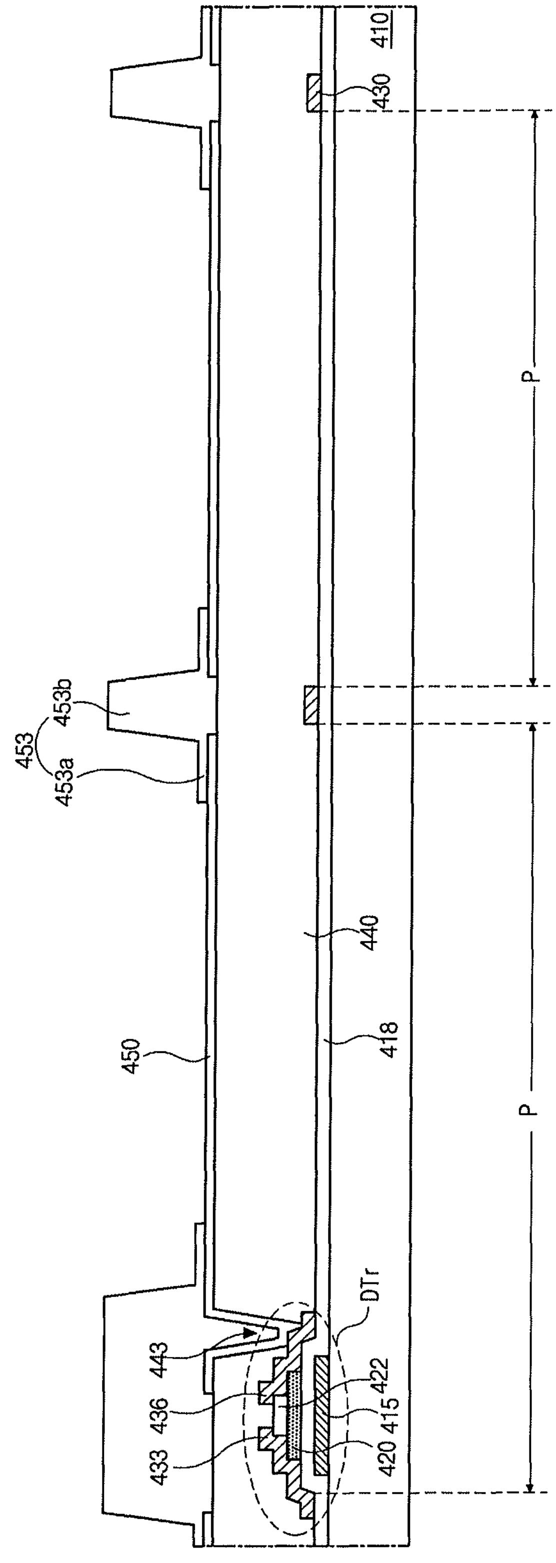

FIG. 11F

METHOD FOR FABRICATING ORGANIC LIGHT EMITTING DIODE DISPLAY DEVICE WITH IMPROVED EFFECTIVE EMITTING PIXELS AREA

The present application claims the benefit of Korean Patent Application No. 10-2012-0134299 filed in Korea on Nov. 26, 2012, which is hereby incorporated by reference for all purposes as if fully set forth herein.

BACKGROUND

1. Field of the Disclosure

The disclosure relates to an organic light emitting diode (OLED) display device, which may be referred to as an organic electroluminescent display device, and more particularly, to an OLED display device having improved aperture ratio and lifetime.

2. Discussion of the Related Art

An OLED display device of new flat panel display devices has high brightness and low driving voltage. The OLED display device is a self-emitting type and has excellent view angle characteristics, contrast ratio, a response time, etc.

Accordingly, the OLED display device is widely used for a television, a monitor, a mobile phone, etc.

The OLED display device includes an array element and an organic light emitting diode. The array element includes a switching thin film transistor (TFT), which is connected to a gate line and a data line, a driving TFT, which is connected to the switching TFT, and a power line, which is connected to the driving TFT. The organic light emitting diode includes a first electrode, which is connected to the driving TFT, and further includes an organic emitting layer and a second electrode.

In the OLED display device, light from the organic emitting layer passes through the first electrode or the second electrode to display an image. A top emission type OLED display device, where the light passes through the second electrode, has an advantage in an aperture ratio.

Generally, the organic emitting layer is formed by a thermal deposition method using a shadow mask. However, the shadow mask sags because the shadow mask becomes larger with an increase in sizes of display devices. As a result, there is a problem in deposition uniformity in the larger display device. In addition, since a shadow effect is generated in the thermal deposition method using the shadow mask, it is very difficult to fabricate a high resolution OLED display device, e.g., above 250 PPI (pixels per inch).

Accordingly, a new method instead of the thermal deposition method using the shadow mask has been introduced.

In the new method, a liquid phase organic emitting material is sprayed or dropped in a region surrounded by a wall using an ink-jet apparatus or a nozzle-coating apparatus and cured to form the organic emitting layer.

FIG. **1** is a schematic cross-sectional view showing an OLED display device in a step of forming an organic emitting layer by spraying or dropping a liquid phase organic emitting material.

To spray or drop the liquid phase organic emitting material by the ink-jet apparatus or the nozzle-coating apparatus, a bank **53**, which is formed on the first electrode **50** and surrounds a pixel region P, is required to prevent the liquid phase organic emitting material from flooding into a next pixel region P. Accordingly, as shown in FIG. **1**, the bank **53** is formed on edges of the first electrode **50** before forming the organic emitting layer **55**.

The bank **53** is formed of an organic material having a hydrophobic property. The hydrophobic bank **53** prevents the organic emitting material, which has a hydrophilic property, from being formed on the bank **53** and flooding into a next pixel region P.

By spraying or dropping the liquid phase organic emitting material from a head of the ink-jet apparatus or a nozzle of the nozzle-coating apparatus into the pixel region P, which is surrounded by the bank **53**, the pixel region P is filled with the organic emitting material. The organic emitting material is dried and cured by heat to form the organic emitting layer **55**.

However, the organic emitting layer **55** has a difference in a thickness. Namely, the organic emitting layer **55** has a thickness in edges being larger than a thickness in a center.

If the organic emitting layer **55** has a thickness difference, the OLED display device has a difference in emitting efficiency. Accordingly, as shown in FIG. **2**, which is a picture showing one pixel region in the related art OLED display device, dark images are displayed in edges of the pixel region. In this instance, since the dark images are perceived as an image defect by the viewer, the edges of the pixel region should be shielded such that the edges of the pixel region do not serve as an effective emission area.

Referring again to FIG. **1**, an effective emission area EA1 is a portion of the pixel region P where the organic emitting layer **55** has a flat top surface. Namely, the aperture ratio of the OLED display device is decreased.

SUMMARY

A method of fabricating an organic light emitting diode display device includes forming a first electrode over a substrate including a display region, which includes a plurality of pixel regions, the first electrode formed in each of the plurality of pixel regions; forming a bank including a lower layer and an upper layer, the lower layer formed on edges of the first electrode and having a first width and a first thickness, and the upper layer formed on the lower layer and having a second width smaller than the first width; forming an organic emitting layer on the first electrode and a portion of the lower layer; and forming a second electrode on the organic emitting layer, the second electrode covering an entire surface of the display region.

In another aspect, an organic light emitting diode display device includes a substrate including a display region, wherein a plurality of pixel regions are defined in the display region; a first electrode over the substrate and in each of the plurality of pixel regions; a bank including a lower layer and an upper layer on the first electrode, the lower layer disposed on edges of the first electrode and having a first width and a first thickness, the upper layer disposed on the lower layer and having a second width smaller than the first width; an organic emitting layer on the first electrode and a portion of the lower layer; and a second electrode on the organic emitting layer and covering an entire surface of the display region.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the invention.

FIG. **1** is a schematic cross-sectional view showing an OLED display device in a step of forming an organic emitting layer by spraying or dropping a liquid phase organic emitting material.

FIG. **2** is a picture showing one pixel region in the related art OLED display device.

FIG. **3** is a circuit diagram of one pixel region of an OLED device.

FIG. **4** is a schematic cross-sectional view of an OLED display device according to an embodiment of the present invention.

FIG. **5** is a schematic cross-sectional view of an OLED display device according to one modified embodiment of the present invention.

FIG. **6** is a schematic cross-sectional view of an OLED display device according to another modified embodiment of the present invention.

FIG. **7** is a picture showing one pixel region in an OLED display device according to the present invention.

FIG. **8** is a schematic cross-sectional view explaining effective emission areas of the related art OLED display device and an OLED display device according to the present invention.

FIGS. **9**A to **9**G are cross-sectional views showing a fabricating process of an OLED display device according to a first embodiment of the present invention.

FIGS. **10**A to **10**F are cross-sectional views showing a fabricating process of on OLED display device according to another example of the first embodiment of the present invention.

FIGS. **11**A to **11**F are cross-sectional views showing a fabricating process of an OLED display device according to a second embodiment of the present invention.

DETAILED DESCRIPTION

Reference will now be made in detail to the preferred embodiments, examples of which are illustrated in the accompanying drawings.

FIG. **3** is a circuit diagram of one pixel region of an OLED device.

As shown in FIG. **3**, an OLED display device includes a switching thin film transistor (TFT) STr, a driving TFT DTr, a storage capacitor StgC and an emitting diode E in each pixel region P.

On a substrate (not shown), a gate line GL along a first direction and a data line DL along a second direction are formed. The gate line GL and the data line DL cross each other to define the pixel region P. A power line PL for providing a source voltage to the emitting diode E is formed to be parallel to and spaced apart from the data line DL.

The switching TFT STr is connected to the gate and data lines GL and DL, and the driving TFT DTr and the storage capacitor StgC are connected to the switching TFT STr and the power line PL. The emitting diode E is connected to the driving TFT DTr.

A first electrode of the emitting diode E is connected to a drain electrode of the driving TFT DTr, and a second electrode of the emitting diode E is grounded.

When the switching TFT STr is turned on by a gate signal applied through the gate line GL, a data signal from the data line DL is applied to the gate electrode of the driving TFT DTr and an electrode of the storage capacitor StgC. When the driving TFT DTr is turned on by the data signal, an electric current is supplied to the emitting diode E from the power line PL. As a result, the emitting diode E emits light. In this case, when the driving TFT DTr is turned on, a level of an electric

current applied from the power line PL to the emitting diode E is determined such that the emitting diode E can produce a gray scale. The storage capacitor StgC serves to maintain the voltage of the gate electrode of the driving TFT DTr when the switching TFT STr is turned off. Accordingly, even if the switching TFT STr is turned off, a level of an electric current applied from the power line PL to the emitting diode E is maintained to a next frame.

FIG. **4** is a schematic cross-sectional view of an OLED display device according to an embodiment of the present invention. FIG. **4** shows one driving TFT DTr in one pixel region P. However, the driving TFT DTr is formed in each pixel region P.

As shown in FIG. **4**, an OLED display device **101** of the present invention includes a first substrate **110**, where a driving TFT DTr, a switching TFT (not shown) and an organic emitting diode E are formed, and a second substrate **170** for encapsulation. The second substrate **170** may be an inorganic insulating film or an organic insulating film.

A gate line (not shown) and a data line **130** are formed on the first substrate **110**. The gate line and the data line **130** cross each other to define the pixel region P. A power line (not shown) for providing a voltage to the emitting diode E is formed to be parallel to and spaced apart from the data line **130**.

In each pixel region P, the switching TFT is connected to the gate line and the data line **130**, and the driving TFT DTr and the storage capacitor StgC are connected to the switching TFT and the power line.

The driving TFT DTr includes a gate electrode **115**, a gate insulating layer **118**, an oxide semiconductor layer **120**, an etch-stopper **122**, a source electrode **133** and a drain electrode **136**. The gate insulating layer **118** covers the gate electrode **115**, and the oxide semiconductor layer **120** is disposed on the gate insulating layer **118**. The oxide semiconductor layer **120** corresponds to the gate electrode **115**. The etch-stopper **122** covers a center of the oxide semiconductor layer **120**. The source electrode **133** and the drain electrode **136** are disposed on the etch-stopper **122** and spaced apart from each other. The source electrode **133** and the drain electrode **136** contact both ends of the oxide semiconductor layer **120**, respectively. Although not shown, the switching TFT has substantially the same structure as the driving TFT DTr.

In FIG. **4**, each of the driving TFT DTr and the switching TFT includes the oxide semiconductor layer **120** of an oxide semiconductor material. Alternatively, as shown in FIG. **5**, each of the driving TFT DTr and the switching TFT may include a gate electrode **213**, a gate insulating layer **218**, a semiconductor layer **220** including an active layer **220***a* of intrinsic amorphous silicon and an ohmic contact layer **220***b* of impurity-doped amorphous silicon, a source electrode **233** and a drain electrode **236**.

Meanwhile, each of the driving TFT DTr and the switching TFT may have a top gate structure where the semiconductor layer is positioned at a lowest layer. Namely, as shown in FIG. **6**, each of the driving TFT DTr and the switching TFT may include a semiconductor layer **313**, which includes an active region **313***a* of intrinsic poly-silicon and impurity-doped regions **313***b* at both sides of the active region **313***a*, on a first substrate **310**, a gate insulating layer **316**, a gate electrode **320** corresponding to the active region **313***a* of the semiconductor layer **313**, an interlayer insulating layer **323** having semiconductor contact holes **325**, which expose the impurity-doped regions **313***b* of the semiconductor layer **313**, and source and drain electrodes **333** and **336** respectively connected to the impurity-doped regions **313***b* through the semiconductor contact holes **325**.

The top gate structure TFT requires the interlayer insulating layer **323** in comparison to a bottom gate structure TFT. In the top gate structure TFT, the gate line (not shown) is formed on the gate insulating layer **316**, and the data line (not shown) is formed on the interlayer insulating layer **323**.

Referring again to FIG. **4**, a passivation layer **140**, which includes a drain contact hole **143** exposing the drain electrode **136** of the driving TFT DTr, is formed over the driving TFT DTr and the switching TFT. For example, the passivation layer **140** may be formed of an organic insulating material, e.g., photo-acryl, to have a flat top surface.

A first electrode **150**, which contacts the drain electrode **136** of the driving TFT DTr through the drain contact hole **143**, is formed on the passivation layer **140** and separately in each pixel region P.

The first electrode **150** is formed of a conductive material having a relatively high work function, e.g., about 4.8 eV to 5.2 eV. For example, the first electrode **150** may be formed of a transparent conductive material such as indium-tin-oxide (ITO) to serve as an anode.

When the first electrode **150** is formed of the transparent conductive material, a reflection layer (not shown) may be formed under the first electrode **150** to increase emission efficiency in a top emission type OLED display device. For example, the reflection layer may be formed of a metallic material, such as aluminum (Al) or Al alloy such as AlNd, having a relatively high reflectivity.

With the reflection layer, the light from an organic emitting layer **155**, which is formed on the first electrode **150**, is reflected by the reflection layer such that the emission efficiency is increased. As a result, the OLED display device has an improved brightness property.

A bank **153** having a double-layered structure, which includes a lower layer **153***a* and an upper layer **153***b*, is formed along boundaries of the pixel region P. The lower layer **153***a* has a first width, and the upper layer **153***b* has a second width narrower than the first width. The lower layer **153***a* of the bank **153** is formed on edges of the first electrode **150** such that a center of the first electrode **150** is exposed by the lower layer **153***a*, and the upper layer **153***b* is disposed on the lower layer **153***a*. The bank **153** includes a hydrophobic material. For example, the bank **153** may be formed of an organic insulating material having a hydrophobic property or an organic insulating material containing a hydrophobic material.

At this time, a thickness of the lower layer **153***a* is thinner than a thickness of the organic emitting layer **155**, which is formed on the lower layer **153***a*. The thickness of the lower layer **153***a* may be within a range of 0.2 micrometers to 1.5 micrometers. Additionally, the lower layer **153***a* is exposed outwards side surfaces of the upper layer **153***b*, and an exposed width of the lower layer **153***a* may be within a range of 1 micrometer to 9 micrometers.

The first width of the lower layer **153***a* is substantially the same as that of the bank **53** having a single-layered structure in the related art OLED display device of FIG. **1**.

In the OLED display device **101** including the bank **153***a* of a double-layered structure, which includes the lower layer **153***a* having the first width and the thickness smaller than the organic emitting layer **155** and the upper layer **153***b* having the second width smaller than the first width, the organic emitting layer **155** is formed on the lower layer **153***a* of the bank **153** exposed outwards the side surfaces of the upper layer **153***b*, and the organic emitting material flows into a center of the pixel region P due to the lower layer **153***a* of the bank **153**. As a result, a problem of an increase in the thickness of the organic emitting layer **155** is reduced in a region adjacent to the bank **153**.

In addition, since the lower layer **153***a* of the bank **153** has substantially the same width as the bank **53** of FIG. **1** of the related art, a region surrounded by the upper layer **153***b* of the bank **153**, which has the second width smaller than the first width of the lower layer **153***a* of the bank **153**, is larger than that surrounded by the bank **53** of the related art when the pixel region has the same size in the present invention and the related art.

Moreover, since the lower layer **153***a* of the bank **153** has the thickness smaller than the organic emitting layer **155**, the organic emitting layer **155** is formed on the lower layer **153***a* of the bank **153**.

Furthermore, since the organic emitting layer **155** on the lower layer **153***a* of the bank **153** has a portion forming a substantially flat top surface with the center of the pixel region P, the flat top surface of the organic emitting layer **155** is increased in the pixel region P, and the organic emitting layer **155** has the flat top surface in a region surrounded by the lower layer **153***a* of the bank **153**.

Accordingly, an emission area EA2, which is defined as a region of the organic emitting layer **155** having the flat top surface, is increased in comparison to the emission area EA **1** of FIG. **1** in the related art OLED display device such that the OLED display device of the present invention has an improved aperture ratio.

FIG. **7** is a picture showing one pixel region in an OLED display device according to the present invention when the OLED display device is driven. Here, the OLED display device includes a bank, which has a double-layered structure including two layers of different widths, and an organic emitting layer, which is formed on the bank and formed of a liquid phase organic emitting material.

Referring to FIG. **7**, the emission area EA2 of FIG. **4** in the OLED display device of the present invention is increased in comparison to the emission area EA1 of FIG. **1** in the related art OLED display device. In addition, uniformity in brightness of the OLED display device of the present invention is improved due to the organic emitting layer **155** of FIG. **4** having the flat top surface all over the emission area EA2 of FIG. **4**.

FIG. **8** is a schematic cross-sectional view explaining effective emission areas of the related art OLED display device and an OLED display device according to the present invention.

As shown in FIG. **8**, with the pixel region of the same size defined by the gate line (not shown) and the data line **30** or **130**, an effective pixel region SP is defined as a region surrounded by the bank **53** or **153**. In this instance, referring to FIG. **8**, the effective pixel region SP in the related art OLED display device is a region surrounded by the bank **53**, while the effective pixel region SP in the OLED display device of the present invention is a region surrounded by the lower layer **153***a* of the bank **153** having the first width. The areas of the effective pixel regions SP in the related art OLED display device and the OLED display device of the present invention are equal to each other.

However, a size of the effective emission area EA2 in the effective pixel region SP of the OLED display device of the present invention is larger than that of the effective emission area EA1 in the effective pixel region SP of the related art OLED display device.

Since the organic emitting layer **55** of the related art OLED display device has different thicknesses in the center and the edge of the effective pixel region SP, the effective emission area EA1 is smaller than the effective pixel region SP. However, since the organic emitting layer **155** of the OLED display device **101** according to the present invention has a uniform thickness in an entire surface of the effective pixel region SP, the effective emission area EA2 is equal to the effective pixel region SP. Namely, a size of the effective emission area EA2 in the effective pixel region SP of the OLED display device of the present invention is larger than that of the effective emission area EA1 in the effective pixel region SP of the related art OLED display device such that the aperture ratio of the OLED display device is increased.

Referring again to FIG. **4**, the organic emitting layer **155** is formed on the first electrode **150** and on the lower layer **153***a* of the bank **153** in an opening of the upper layer **153***b* of the bank **153**. The organic emitting layer **155** includes red, green and blue emitting materials in respective pixel regions P.

The organic emitting layer **155** is formed by forming an organic emitting material layer and curing the organic emitting material layer. The organic emitting material layer is formed by coating, i.e., spraying or dropping a liquid phase organic emitting material by an ink-jet apparatus or a nozzle-coating apparatus.

FIG. **4** shows a single-layered organic emitting layer **155**. Alternatively, to improve emission efficiency, the organic emitting layer **155** may have a multi-layered structure. For example, the organic emitting layer **155** may include a hole injecting layer, a hole transporting layer, an emitting material layer, an electron transporting layer and an electron injecting layer stacked on the first electrode **150** as an anode. The organic emitting layer **155** may be a quadruple-layered structure of the hole transporting layer, the emitting material layer, the electron transporting layer and an electron injecting layer or a triple-layered structure of the hole transporting layer, the emitting material layer and the electron transporting layer.

A second electrode **160** is formed on the organic emitting layer **155** and covers an entire surface of a display region of the first substrate **110**. The second electrode **160** is formed of a metallic material having a relatively low work function, e.g., Al, Al alloy, silver (Ag), magnesium (Mg), gold (Au), or Al—Mg alloy (AlMg). The second electrode **160** serves as a cathode.

The first electrode **150**, the organic emitting layer **155** and the second electrode **160** constitute the emitting diode E.

A seal pattern (not shown) of a sealant or a frit material is formed on edges of the first substrate **110** or the second substrate **170**. The first and second substrates **110** and **170** are attached using the seal pattern. A space between the first and second substrates **110** and **170** has a vacuum condition or an inert gas condition. The second substrate **170** may be a flexible plastic substrate or a glass substrate.

Alternatively, the second substrate **170** may be a film contacting the second electrode **160**. In this instance, the film-type second substrate is attached to the second electrode **160** by an adhesive layer.

In addition, an organic insulating film or an inorganic insulating film may be formed on the second electrode **160** as a capping layer. In this instance, the organic insulating film or the inorganic insulating film serves as the encapsulation film without the second substrate **170**.

In the OLED display device **101** including the lower layer **153***a* of the bank **153**, which has the thickness being smaller than the organic emitting layer **155** and has a hydrophobic property, and the upper layer **153***b* of the bank **153**, which has the second width smaller than the first width of the lower layer **153***a*, the organic emitting layer **155** is formed on the lower layer **153***a* and the organic emitting material is concentrated into a center of the pixel region P by the lower layer **153***a*. As a result, a problem of an increase in the thickness of the organic emitting layer **155** is reduced in a region adjacent to the lower layer **153***a*.

In addition, since the organic emitting layer **155** on the lower layer **153***a* of the bank **153** has a portion forming a substantially flat top surface with the center of the pixel region P, the organic emitting layer **155** has a uniform thickness in a region surrounded by the lower layer **153***a* of the bank. As a result, an emission area EA2 is increased in comparison to the emission area EA1 of FIG. **1** in the related art OLED display device such that the OLED display device of the present invention has the improved aperture ratio.

Moreover, since an area having thickness uniformity of the organic emitting layer **155** is increased, brightness uniformity of the OLED display device of the present invention is improved. Furthermore, due to the thickness uniformity of the organic emitting layer **155**, a thermal degradation problem of the organic emitting layer is prevented such that the OLED display device has an improved lifetime.

Hereinafter, a method of fabricating the OLED display device is explained with reference to FIGS. **9**A to **9**G. FIGS. **9**A to **9**G are cross-sectional views showing a fabricating process of an OLED display device according to a first embodiment of the present invention. The explanation is focused on a bank having a double-layered structure with different widths.

As shown in FIG. **9**A, on the first substrate **110**, the gate line (not shown), the data line (not shown) and the power line (not shown) are formed. In addition, the switching TFT (not shown) connected to the gate and data lines and the driving TFT DTr connected to the switching TFT and the power line are formed.

As explained above, each of the switching TFT and the driving TFT DTr has a bottom gate type TFT including the gate electrode **115** of FIG. **4** or **213** of FIG. **5** as a lowest layer or a top gate type TFT including the semiconductor layer **313** of FIG. **6** as a lowest layer. The bottom gate type TFT includes the oxide semiconductor layer **120** of FIG. **4** or the amorphous silicon semiconductor layer **220** of FIG. **5** including the active layer **220***a* and the ohmic contact layer **220***b*, and the top gate type TFT includes the poly-silicon semiconductor layer **313** of FIG. **6**.

Here, the switching TFT and the driving TFT DTr may be the bottom gate type TFT including an oxide semiconductor layer. Therefore, the gate electrode **115** of the driving TFT DTr is formed on the first substrate **110**, the gate insulating layer **118** is formed on the gate electrode **115**, and the oxide semiconductor layer **120** is formed on the gate insulating layer **118** corresponding to the gate electrode **115**. The etch-stopper **122** is formed on the oxide semiconductor layer **120** and covers the center of the oxide semiconductor layer **120**. The source and drain electrodes **133** and **136** are formed on the etch-stopper **122** and spaced apart from each other.

Next, an organic insulating material, e.g., photo-acryl, is coated over the switching TFT and the driving TFT DTr and is patterned to form the passivation layer **140** having a flat top surface and including the drain contact hole **143**. The drain electrode **136** of the driving TFT DTr is exposed through the drain contact hole **143**.

Next, a transparent conductive material, which has a relatively high work function, is deposited on the passivation layer **140** and patterned to form the first electrode **150**. The first electrode **150** contacts the drain electrode **136** of the driving TFT DTr through the drain contact hole **143** and is separated in each pixel region P. For example, the transparent conductive material may be indium tin oxide (ITO).

Meanwhile, as explained above, the reflection layer (not shown), which includes Al or Al alloy, may be formed under the first electrode **150** and on the passivation layer **140**. The reflection layer may be formed by the same mask process as the first electrode **150**.

Next, as shown in FIG. **9**B, a bank material layer **151** is formed on the first electrode **150** and the passivation layer **140**. For example, the bank material layer **151** may be formed by coating a polymer material having a hydrophobic property. The polymer material may include at least one of polyimide containing fluorine (F), styrene, methylmethacrylate, and polytetrafluoroethylene. At this time, the polymer material may include a photosensitive material having a photosensitive property.

An exposing mask **198** including a transmitting region TA, a blocking region BA and a half-transmitting region HTA is disposed over the bank material layer **151**, and an exposing process to the bank material layer **151** is performed using the exposing mask **198** without an additional photoresist layer.

Here, the bank material layer **151** is shown to have a negative type photosensitive property where an exposed portion of the bank material layer **151** remains after a developing process. Alternatively, the bank material layer **151** may have a positive type photosensitive property, and at this time, a position of the transmitting region TA and the blocking region BA is switched.

Next, as shown in FIG. **9**C, the bank **153** including the lower layer **153***a* and the upper layer **153***b* is formed by developing the bank material layer **151** of FIG. **9**B exposed to light. In this instance, an exposed portion of the bank material layer **151** of FIG. **9**B corresponding to the transmitting region TA of the exposing mask **198** remains to form the upper layer **153***b* having the same thickness as the bank material layer **151** of FIG. **9**B, a non-exposed portion of the bank material layer **151** corresponding to the blocking region BA of the exposing mask **198** is removed by the developing process, and a partially-exposed portion of the bank material layer **151** of FIG. **9**B is partially removed to form the lower layer **153***a* having the thickness smaller than that of the upper layer **153***b*.

Accordingly, after the developing process, the bank **153** having the double-layered structure is formed in the edge of each pixel region P such that the upper layer **153***b* having the second width is disposed in a center of the edge of each pixel region P and the lower layer **153***a* having the first width larger than the second width is exposed outwards the side surfaces of the upper layer **153***b*. The exposed width of the lower layer **153***a* may be 1 micrometer to 9 micrometers, and the thickness of the lower layer **153***a* may be 0.2 micrometers to 1.5 micrometers.

Meanwhile, the bank material layer **151** of FIG. **9**B may include a hydrophobic polymer material without a photosensitive property. This will be explained as another example of the first embodiment with reference to FIGS. **10**A to **10**F. FIGS. **10**A to **10**F are cross-sectional views showing a fabricating process of on OLED display device according to another example of the first embodiment of the present invention.

As shown in FIG. **10**A, a bank material layer **151** is formed on the first electrode **150** all over the first substrate **110**. The bank material layer **151** may be formed by coating a polymer material having a hydrophobic property without a photosensitive property.

Next, a photoresist layer **195** is formed on the bank material layer **151** by applying photoresist.

Then, an exposing mask **198** including a transmitting region TA, a blocking region BA and a half-transmitting region HTA is disposed over the photoresist layer **195**, and an exposing process to the photoresist layer **195** is performed using the exposing mask **198**.

Here, the photoresist layer **195** is shown to have a negative type photosensitive property where an exposed portion of the photoresist layer **195** remains after a developing process. The exposing mask **198** is disposed such that the transmitting region TA and the half-transmitting region HTA correspond to the edge of each pixel region P, and the blocking region BA corresponds to the center of the pixel region P.

Next, as shown in FIG. **10**B, a first photoresist pattern **195***a* and a second photoresist pattern **195***b* are formed by developing the photoresist layer **195** of FIG. **10**A exposed to light through the exposing mask **198**. In this instance, an exposed portion of the photoresist layer **195** of FIG. **10**A corresponding to the transmitting region TA of the exposing mask **198** remains to form the first photoresist pattern **195***a* having a first thickness the same as the photoresist layer **195** of FIG. **10**A, a non-exposed portion of the photoresist layer **195** of FIG. **10**A corresponding to the blocking region BA of the exposing mask **198** is removed by the developing process, and a partially-exposed portion of the photoresist layer **195** of FIG. **10**A is partially removed to form the second photoresist pattern **195***b* having a second thickness smaller than the first thickness.

In FIG. **10**C, a bank pattern **152** is formed under the first and second photoresist patterns **195***a* and **195***b* by removing the bank material layer **151** of FIG. **10**B exposed by the first and second photoresist patterns **195***a* and **195***b* through an etching process. The bank pattern **152** is disposed in the edge of the pixel region P and has a uniform thickness.

Next, in FIG. **10**D, the second photoresist pattern **195***b* of FIG. **10**C having the second thickness is removed by performing an ashing process, and the bank pattern **152** is partially exposed outwards side surfaces of the first photoresist pattern **195***a*. Here, the first photoresist pattern **195***a* is also partially removed, so that the thickness of the first photoresist pattern **195***a* is reduced.

In FIG. **10**E, the bank pattern **152** of FIG. **10**D exposed by the first photoresist pattern **195***a* is dry-etched and partially removed to thereby form the lower layer **153***a* of the bank **153** such that the lower layer **153***a* of the bank **153** has a thickness of 0.2 micrometers to 1.5 micrometers. At the same time, a portion of the bank pattern **152** of FIG. **10**D, which is disposed under the first photoresist pattern **195***a* and is not dry-etched, becomes the upper layer **153***b* of the bank **153**.

Here, the width of the lower layer **153***a* of the bank **153** exposed outwards the side surfaces of the upper layer **153***b* of the bank **153** may be 1 micrometer to 9 micrometers.

Next, as shown in FIG. **10**F, the first photoresist pattern **195***a* of FIG. **10**E is removed by performing a stripping process, thereby completing the bank **153** of the double-layered structure having the different widths in another example of the first embodiment.

In the meantime, as shown in FIG. **9**D, after forming the bank **153** having the double-layered structure, an organic emitting material layer **154** is formed on the first electrode **150** and the lower layer **153***a* of the bank **153** by spraying or dropping a liquid phase organic emitting material in a region surrounded by the upper layer **153***b* of the bank **153** with an ink-jet apparatus or a nozzle-coating apparatus.

Even if the organic emitting material is sprayed or dropped on the upper layer **153***b* because of a mis-alignment of the ink-jet apparatus or the nozzle-coating apparatus, the organic emitting material is concentrated into a center of the pixel region P because the material of the upper layer **153***b* has a hydrophobic property. In addition, even if an excessive amount of the organic emitting material is sprayed or dropped, the organic emitting material does not flow over the upper layer **153***b* due to the hydrophobic property of the upper layer **153***b*.

Furthermore, since the lower layer **153***a* has a thickness smaller than the organic emitting material layer **154**, the organic emitting material layer **154** is also formed on the lower layer **153***a* even though the lower layer **153***a* has a hydrophobic property.

Next, as shown in FIG. **9**E, by performing a curing process, solvents and moisture in the organic emitting material layer **154** of FIG. **9**D are removed such that the organic emitting layer **155** is formed in each pixel region P.

As mentioned above, since the organic emitting layer **155** has a uniform thickness in an entire surface of the effective pixel region SP of FIG. **8**, the OLED display device of the present invention has the improved aperture ratio. Namely, since the organic emitting layer **155** on a portion of the lower layer **153***a* has a flat top surface with the organic emitting layer **155** in a center of the pixel region P, the effective emission area EA2 of FIG. **8** is enlarged in comparison to the effective emission area EA1 of FIG. **8** of the related art OLED display device.

Here, the organic emitting layer **155** has a single-layered structure. Alternatively, to improve emission efficiency, the organic emitting layer **155** may have a multi-layered structure. For example, the organic emitting layer **155** may include a hole injecting layer, a hole transporting layer, an emitting material layer, an electron transporting layer and an electron injecting layer stacked on the first electrode **150** as an anode. The organic emitting layer **155** may be a quadruple-layered structure of the hole transporting layer, the emitting material layer, the electron transporting layer and an electron injecting layer or a triple-layered structure of the hole transporting layer, the emitting material layer and the electron transporting layer.

Next, as shown in FIG. **9**F, the second electrode **160** is formed on the organic emitting layer **155** by depositing a metallic material having a relatively low work function. The second electrode **160** is formed on an entire surface of a display region. The metallic material includes at least one of Al, Al alloy such as AlNd, Ag, Mg, Au and AlMg.

As explained above, the first electrode **150**, the organic emitting layer **155** and the second electrode **160** constitute the emitting diode E.

Next, as shown in FIG. **9**G, after forming a seal pattern (not shown) on edges of the first substrate **110** or the second substrate **170**, the first and second substrates **110** and **170** are attached under a vacuum condition or an inert gas condition such that the OLED display device is fabricated. Alternatively, a paste seal (not shown), which is formed of a fit material, an organic insulating material or a polymer material, having transparent and adhesive properties is formed over an entire surface of the first substrate **110**, and then the first and second substrates **110** and **170** are attached. As explained above, instead of the second substrate **170**, an inorganic insulating film or an organic insulating film may be used for an encapsulation.

FIGS. **11**A to **11**F are cross-sectional views showing a fabricating process of an OLED display device according to a second embodiment of the present invention. Since other steps except for a step of forming a bank in the second embodiment are the same as those in the first embodiment, the explanation is focused on a bank having a double-layered structure with different widths, and explanations for other steps are omitted.

As shown in FIG. **11**A, a switching TFT (not shown), a driving TFT DTr, a gate insulating layer **418**, a gate line (not shown), a data line **430**, a passivation layer **440**, and a first electrode **450** are formed on a first substrate **410**. A bank material layer **451** is formed on the first electrode **450** and the passivation layer **440**. For example, the bank material layer **451** may be formed by coating a polymer material having a hydrophobic property without a photosensitive property. A photoresist layer **495** is formed on the bank material layer **451** by applying photoresist.

Next, an exposing mask **498** including a transmitting region TA and a blocking region BA is disposed over the photoresist layer **495**, and an exposing process to the photoresist layer **495** is performed using the exposing mask **498**.

Here, the photoresist layer **495** is shown to have a negative type photosensitive property where an exposed portion of the photoresist layer **495** remains after a developing process. The transmitting region TA corresponds to edges of a pixel region P, and the blocking region BA corresponds to a center of the pixel region P.

In FIG. **11**B, a first photoresist pattern **496** is formed by developing the photoresist layer **495** of FIG. **11**A exposed to light through the exposing mask **498**. In this instance, an exposed portion of the photoresist layer **495** of FIG. **11**A corresponding to the transmitting region TA of the exposing mask **498** of FIG. **11**A remains to form the first photoresist pattern **496** having a first thickness the same as the photoresist layer **495** of FIG. **11**A, and a non-exposed portion of the photoresist layer **495** of FIG. **11**A corresponding to the blocking region BA of the exposing mask **498** of FIG. **11**A is removed by the developing process.

Next, in FIG. **11**C, a bank pattern **452** is formed under the first photoresist pattern **496** and **496** by removing the bank material layer **451** of FIG. **11**B exposed by the first photoresist pattern **496** through an etching process. The bank pattern **452** is disposed in the edge of the pixel region P and has a uniform thickness.

Next, in FIG. **11**D, a second photoresist pattern **496***a* is formed by partially removing upper and side portions of the first photoresist pattern **496** of FIG. **11**C having the uniform thickness through an isotropic ashing process, and the bank pattern **152** is exposed outwards side surfaces of the second photoresist pattern **496***a*. The second photoresist pattern **496***a* has a second thickness smaller than the first thickness of the first photoresist pattern **496** of FIG. **11**C and a width smaller than that of the first photoresist pattern **496** of FIG. **11**C.

The exposed portion of the bank pattern **452** may have a width of 1 micrometer to 9 micrometers, and the width of the exposed portion of the bank pattern **452** may be controlled by adjusting ashing time or flow rates of ashing gases.

Meanwhile, residues of the bank material layer **451** of FIG. **11**B may remain after the etching process, and the residues may hinder a liquid phase organic emitting material from being spread because the bank material layer **451** of FIG. **11**B has the hydrophobic property. However, in the second embodiment of the present invention, the residues of the bank material layer **451** of FIG. **11**B can be completely removed through the isotropic ashing process, and the organic emitting material can be spread well when it is dropped.

Next, in FIG. **11**E, the bank pattern **452** of FIG. **11**D exposed by the second photoresist pattern **496***a* is anisotropically dry-etched and partially removed using gases reacting with the bank pattern **452** of FIG. **11**D to thereby form a lower layer **453***a* of a bank **453** such that the lower layer **453***a* of the bank **453** has a thickness of 0.2 micrometers to 1.5 micrometers. At the same time, a portion of the bank pattern **452** of FIG. **11**D, which is disposed under the second photoresist pattern **296***a* and is not anisotropically dry-etched, becomes an upper layer **453***b* of the bank **453**.

Then, as shown in FIG. **11**F, the second photoresist pattern **496***a* of FIG. **11**E is removed by performing a stripping process to thereby complete the bank **453** of a double-layered structure that includes the lower layer **453***a* and the upper layer **453***b* having the different widths. The width of the lower layer **453***a* of the bank **453** is within a range of 0.2 micrometers to 1.5 micrometers. The upper layer **453***b* of the bank **453** overlaps a center of the lower layer **453***a* of the bank **453**.

Here, the width of the lower layer **453***a* of the bank **453** exposed outwards side surfaces of the upper layer **453***b* of the bank **453** may be 1 micrometer to 9 micrometers.

In the second embodiment of the present invention, the bank **453** including the lower layer **453***a* and the upper layer **453***b* of different widths is formed without use of an exposing mask, which includes a half-transmitting region and is relatively expensive. Therefore, the manufacturing costs are lowered.

Moreover, residues of the hydrophobic polymer material on the first electrode **450** can be completely removed during the ashing process of the first photoresist pattern, and thus the liquid phase organic emitting material can be spread well when the organic emitting layer is formed.

In the OLED display device of the invention, the effective emission area, where the organic emitting layer has a flat top surface, i.e., a uniform thickness, is increased due to the lower layer and the upper layer of the bank having different widths. As a result, the aperture ratio of the OLED display device is improved.

Furthermore, since an area of the organic emitting layer having the flat top surface increases in the pixel region, the brightness of the device is uniform, and display qualities are improved.

In addition, since the lower layer and the upper layer of the bank are formed in a single mask process, there are advantages in the production costs and the fabricating process.

Moreover, the uniformity in the thickness of the organic emitting layer is increased due to the lower layer of the bank, and the organic emitting layer is prevented from being degraded, thereby lengthening lifetime of the device.

It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method of fabricating an organic light emitting diode display device, comprising:

forming a single layer first electrode directly contacting over a substrate including a display region, which includes a plurality of pixel regions, the single layer first electrode formed in each of the plurality of pixel regions;

forming a bank including a lower layer and an upper layer, the lower layer formed on edges of the single layer first electrode and having a first width and a first thickness, and the upper layer formed on the lower layer and having a second width smaller than the first width, wherein the forming of the bank includes:

applying directly a polymer material having a hydrophobic property by itself on the single layer first electrode to form a hydrophobic property bank material layer; and

patterning the hydrophobic property bank material layer to form the lower layer and the upper layer each having the hydrophobic property by itself;

forming an organic emitting layer directly contacting the single layer first electrode and directly contacting a portion of the lower layer; and

directly forming a single second electrode layer directly in contact with the entire organic emitting layer, the single second electrode layer covering an entire surface of the display region.

2. The method according to claim **1**, wherein the lower layer and the upper layer include a same material having a hydrophobic property.

3. The method according to claim **1**, wherein the first thickness is smaller than a thickness of the organic emitting layer and is within a range of about 0.2 to 1.5 micrometers.

4. The method according to claim **1**, wherein a width of the lower layer exposed outwards side surfaces of the upper layer is within a range of about 1 to 9 micrometers.

5. The method according to claim **1**, wherein the organic emitting layer on the portion of the lower layer has a flat top surface with the organic emitting layer on a center of the pixel region.

6. The method according to claim **5**, wherein forming the organic emitting layer includes:

applying a liquid phase organic emitting material using an ink-jet apparatus or a nozzle-coating apparatus; and

curing the organic emitting material to form the organic emitting layer.

7. The method according to claim **1**, wherein forming the bank includes:

forming a bank material layer on the first electrode by applying a polymer material having a hydrophobic property and a photosensitive property;

exposing the bank material layer to light through an exposing mask including a transmitting region, a blocking region and a half-transmitting region; and

patterning the bank material layer exposed to light.

8. The method according to claim **1**, wherein forming the bank includes:

forming a bank material layer on the first electrode by applying a polymer material having a hydrophobic property;

forming a photoresist layer on the bank material layer;

exposing the photoresist layer to light through an exposing mask including a transmitting region, a blocking region and a half-transmitting region;

developing the photoresist layer exposed to light to form a first photoresist pattern and a second photoresist pattern, the first photoresist pattern having a thickness larger than the second photoresist pattern;

patterning the bank material layer using the first and second photoresist patterns as an etching mask to form a bank pattern;

removing the second photoresist pattern by performing an ashing process to expose the bank pattern corresponding to the second photoresist pattern and to reduce the thickness of the first photoresist pattern;

anisotropically dry-etching the bank pattern using the first photoresist pattern having the reduced thickness as an etching mask to form the lower layer and the upper layer of the bank; and

stripping the first photoresist pattern to expose the upper layer of the bank.

9. The method according to claim **1**, wherein forming the bank includes:

forming a bank material layer on the first electrode by applying a polymer material having a hydrophobic property;

forming a photoresist layer on the bank material layer;

exposing the photoresist layer to light through an exposing mask including a transmitting region and a blocking region;

developing the photoresist layer exposed to light to form a first photoresist pattern;

patterning the bank material layer using the first photoresist pattern as an etching mask to form a bank pattern;

partially removing the first photoresist pattern by performing an isotropic ashing process to form a second photoresist pattern having a width and a thickness smaller than the first photoresist pattern and to expose the bank pattern outwards side surfaces of the second photoresist pattern;

anisotropically dry-etching the bank pattern using the second photoresist pattern as an etching mask to form the lower layer and the upper layer of the bank; and

stripping the second photoresist pattern to expose the upper layer of the bank.

10. The method according to claim **1**, wherein the organic emitting layer has a second thickness larger than the first thickness.

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